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COMPLEX OF MICROFAUNA OF PALEOGENIC SEDIMENTS AND RECONSTRUCTION OF THE BIONOMY OF THE BASIN BASED ON THE CUT OF KHILMILLI IN THE GOBUSTAN REGION OF SOUTH-EAST CAUCASUS

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Summary. The paper is devoted to the biostratigraphic subdivision of the Paleogene deposits in Southeastern Gobustan. The subdivision was carried out on the basis of materials obtained from the Khilmilli section. Foraminiferal studies were conducted on samples collected from this section. The stratigraphic division of the Paleogene deposits in the studied area is thoroughly substantiated by foraminiferal data and traced throughout the Khilmilli section. Based on the rich foraminiferal assemblages within the section, the detailed stage- and zone-level subdivision of the Paleogene sequence was established. According to the microfaunal evidence, the Paleogene deposits are divided into the Paleocene, Eocene, and Oligocene series and their respective stages. It was determined that the rocks of the Danian and Thanetian (Paleocene), Ypresian, Lutetian, Bartonian, and Priabonian (Eocene), as well as the Rupelian (Oligocene) stages are represented in the Khilmilli section. Continuous tracing of the microfauna across the section allowed a precise interpretation of the complex composition of zones and changes within them. The distribution of foraminifera by zones was followed, and their development across the stages was described. At the same time, deposits of the Selandian stage were not detected in the section. Comprehensive data on the bionomy of the basin have also been provided.

Keywords: *Foraminifera, fauna, Paleocene, Eocene, Oligocene, plankton, basin, Paleogene, microfauna*

Introduction

Gobustan is one of the areas in Azerbaijan where the Paleogene deposits are widely distributed. These deposits participate in the formation of the entire geological structure in the region (Ахмедов, 1957). Since the Paleogene deposits are also related to several mineral deposits, clarification of their stratigraphic subdivision scheme is essential (Fig. 1) (Халилов, Мамедова, 1984).

The microfauna of these deposits were studied by micropaleontologists Aghalarova D.A., Jafarov J.I., Khalilov D.M (Халилов, 1962), Veber V.V., Voroshilova A.G. and others (Ворошилова, 1967). The Paleogene deposits sharply differ in lithological composition both horizontally and vertically across regions and are characterized by diverse fossil faunas (Вебер, 1930). Based on microfauna, the Paleogene deposits are divided into Paleocene, Eocene and Oligocene subdivisions and stages (Babayev və b., 2015).

Materials and Methods

The researches were conducted in Gobustan district of the Southeastern Caucasus. In this area, the Paleogene deposits of the Khilmilli section were studied. For the purposes of studying the complex microfauna of the Paleogene deposits in Gobustan district and restoration of the basin bionomy, 16 samples were collected from the Khilmilli section, and their paleontological analysis was conducted, stage and zonal subdivision of foraminifera of the Paleogene deposits of Gobustan district were provided on the basis of the identified rich foraminiferal assosication (Ализаде, 1989).

Fig. 1. Geological map of the distribution of the Paleogene deposits in Gobustan district

Fig. 2. The exposure of the Paleocene deposits in the Khilmilli section

Collection of microfauna was carried out using a Nikon SMZ18 microscope, and images were obtained using a ZEISS Stemi 508 scanning electron microscope. The sample was studied using micropaleontological analysis. The sequential distribution and zonal subdivision of microfauna of the Paleogene deposits were observed in the Khilmilli section (Fig. 2).

The Paleocene. The Paleocene is divided into the Danian, Selandian, and Thanetian stages in the studied region. These deposits belong to the Ilkhydagh and Sumgayit successions.

The Lower Paleocene. The Danian stage. The Ilkhydagh succession belongs to this stage. The deposits of the Danian stage of the Khilmilli section of Gobustan are subdivided into two zones from bottom to top: *Globoconusa daubjergensis* and *Acarinina incostans*.

The deposits of *Globoconusa daubjergensis* zone conformably lie over the Maastrichtian sediments on the right bank of the Qozluchay, 1-1.5 km east of the Khilmilli village. Here, the Danian deposits consist of thinly interbedded, commonly found coarse-grained, hard, yellowish sandstones and thinly bedded gray, dark grey marly clays (Fig. 2). *Eponides trumpyi, Heterohelix irregularis, Globigerina varianta, G. moskvini, G. pseudobulloides, Bairdia ilaroensis*, etc. were determined from these deposits (Allahverdiyeva, 2014).

In the Khilmilli section, the deposits of the *Acarinina incostans* zone of the Danian stage are distributed together with the deposits of the underlying zone (Fig. 3) (Allahverdiyeva, 2012).

In this section, the deposits of the *Acarinina inconstans* zone conformably lie over the deposits of the lower zone occurring in the same lithofacies, reaching thicknesses of up to 20 m, and are characterized by *Eponides trumpyi, Heterohelix irregularis, H. pumilia, H. crinita, H. midwayensis, Acarinina inconstans*, etc.

The Upper Paleocene: The Selandian and Thanetian stages are distinguished within the Sumgayit successions.

The deposits of the Selandian stage were not been detected in the Khilmilli section.

The Thanetian stage deposits were subdivided from bottom to top, into the *Globorotalia conicotruncata–Acarinina subsphaerica* and *Globorotalia aequa–Acarinina clara* zones (Халилов, Мамедова, 1984).

In contrast, our studies of the Khilmilli section reveal that, the sequence is subdivided from bottom to top into the *Acarinina subsphaerica* and *Acarinina acarinata* zones within the Thanetian stage.

According to our researches, the Thanetian stage is subdivided into two zones in the Khilmilli section from bottom to top: *Acarinina subsphaerica* and *Acarinina acarinata*.

Acarinina subsphaerica zone is represented by greenish-gray, dark gray, and gray marly clays in the Khilmilli (50 m) section and they are replaced upward by sandstone interbeds within brick-red to greenish-gray clays. *Globorotalia compressa, Acarinina subsphaerica, Globigerina varianta, G. triloculinoides, Ammodiscus incertus, Rhabdammina cylindrica, Glomospira corona*, etc. are distributed in these sediments. The Upper Paleocene lies over the layers of the Danian stage in the Khilmilli section transgressively. (Allahverdiyeva, 2014)

The Upper Acarinina acarinata zone of the Thanetian stage is represented by alternation of interbeds of brick-red, reddish-brown, and greenish-gray clays with sandstone interlayers in the Khilmilli section. The thickness of these deposits varies between 10-100 m, and they lie conformably over the underlying sediments. *Globigerina triloculinoides, G. eoceanica, G. quadrilobulinoides, G. nana, G. compressaformis, G. velascoensis, Globorotalia chapmani, G. occlusa, Acarinina intermedia, Ac. primitiva, Ac. acarinata, Glomospira corona*, etc. are distributed in these deposits (Fig. 4).

The Eocene. The Qovundagh succession belongs to the Eocene in the Southeastern Caucasus. The Qovundagh succession is divided into lower, middle, and upper horizons based on field color. According to the local subdivision, the Ypresian stage belongs to the Lower Qovundagh, the Lutetian and Bartonian stages belong to the Middle Qovundagh, and the Priabonian stage belongs to the Upper Qovundagh. These sediments are mainly characterized by the planktonic foraminifera.

The Qovundagh sediments of the Paleogene are oil-bearing in the region (Aghayeva et al., 2023).

The Lower Eocene sediments are separated within the Ypresian stage and subdivided from bottom to top into three microfaunal zones:

Globorotalia subbotinae, Globorotalia marginodentata, and *Globorotalia aragonensis*.

The deposits of the *Globorotalia subbotinae* zone lie conformably over the Upper Paleocene deposits in the Khilmilli section. They are represented by alternations of thin-bedded gray clays with rare sandstone interbeds. The thickness is 10 m. *Anomalina* ex. gr. *affinis, Globorotalia marginodentata, Gl. subbotinae, Bolivina aduncoscostata longa, Acarinina interposita, Globigerina triloculinoides*, etc. were distributed here (Fig. 4).

In the Khilmilli section, since the *Globorotalia marginodentata* and *Globorotalia aragonensis* zones could not be distinguished, this zone lies transgressively over the sediments of the lower zone.

The Middle Eocene. The Lutetian and Bartonian Stages. It is characterized by the instability of the Qovundagh lithofacies and its thickness.

Acarinina bullbrooki, Acarinina rotundimarginata, and *Hantkenina alabamensis* zones are distinguished in the Lutetian stage of this region.

In the Khilmilli section, the deposits of *Acarinina bullbrooki* zone consist of alternation of gray clay layers. Thin, fine-grained clayey sandstone layers are occasionally encountered among them. Thick-bedded (5 m) clay lies at the lower part of this zone. Total thickness is 19 m. *Acarinina bullbrooki, Anomalina simplex, Globigerina eoceanica, Asterigerina bartoniana, Tritaxilina indentata* were detected here.

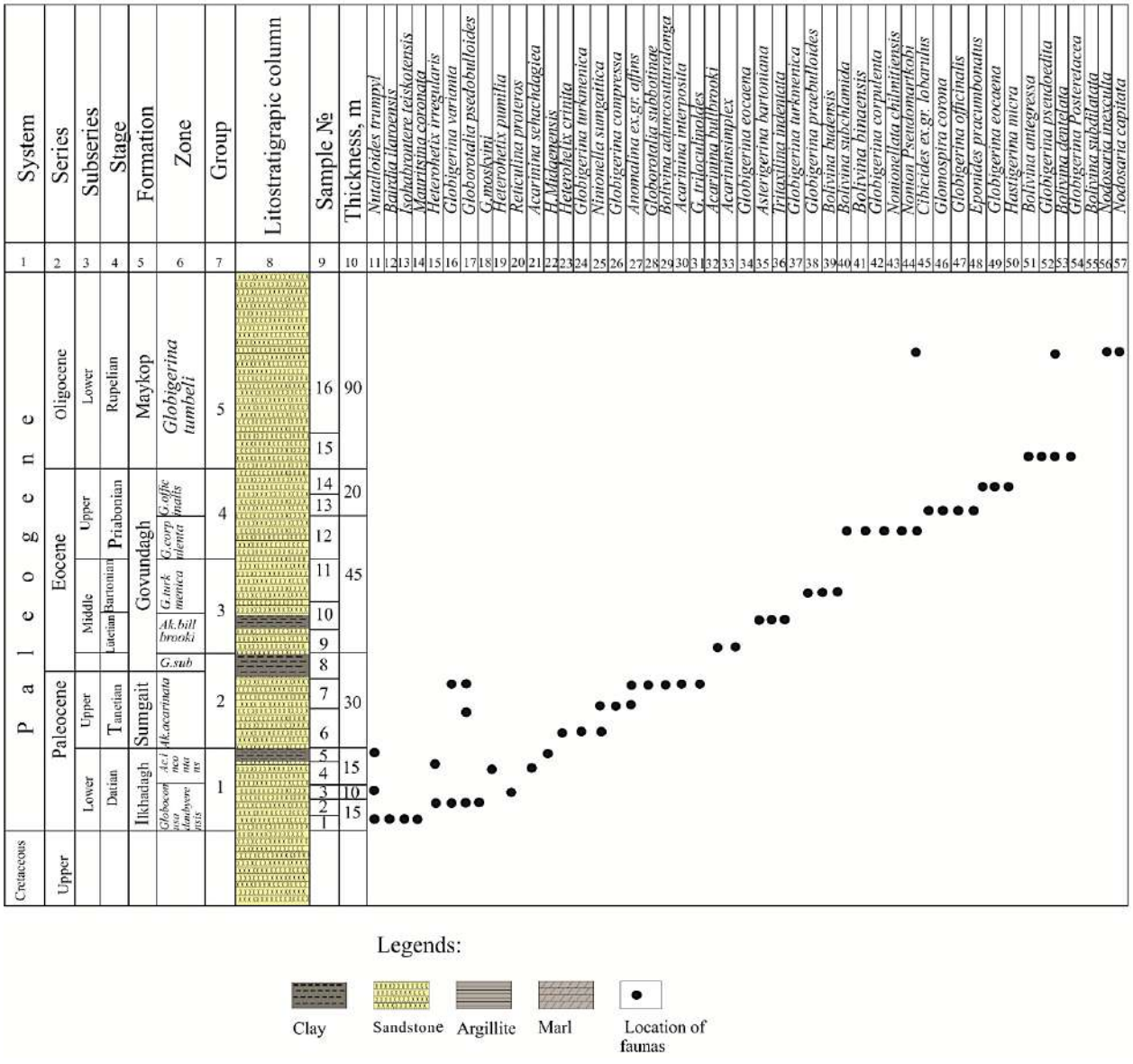

Fig. 3. Distribution of the microfauna in the Khilmilli section

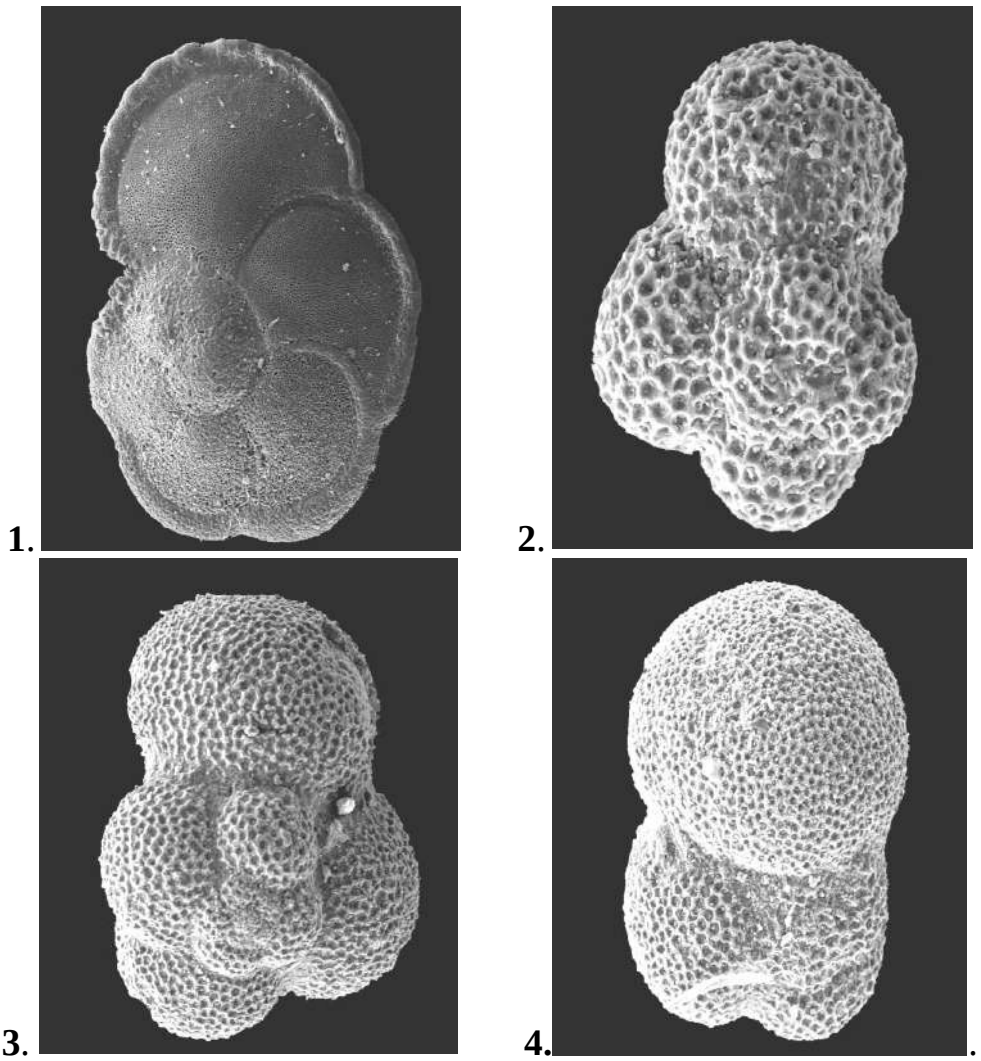

Fig. 4. Microfaunal Complex of the Paleogene Sediments:
1 – *Globorotalia marginodentata* Subbotina; **2** – *Globigerina eocaenica*; **3** – *Globigerina bulloides* Orbigny; **4** – *Acarinina acarinata* Subbotina

The *Globigerina turkmenica* zone is distinguished in sediments of the Bartonian stage. This zone is well developed in the Khilmilli section. It is composed of thin to medium (10-30 cm) sandstone interbeds alternating with greenish-gray, reddish, marly clays, and sandy clays. *Globigerina turkmenica, G. praebulloides, Bolivina budensis, Hastigerina micra, Globigerina ouachitaensis, Nonion adgerensis, Cibicides ungerianus*, etc. are distributed in these deposits.

In the Khilmilli section, the sediments of this zone lie over the sediments of the lower zone transgressively. *Acarinina rotundimarginata* and *Hantkenina alabamensis* zones have not been distinguished in the Khilmilli section.

The Upper Eocene. The Priabonian Stage. The Priabonian deposits are subdivided into *Globigerina corpulenta* and *Globigerina officinalis* zones. In the Khilmilli section, the *Globigerina corpulenta* zone is represented by sandstone interbeds alternating with dark-gray clays. *Globigerina corpulenta, G. eoceanica, G. inflata, G. praebulloides, Globigerapsis index, G. ouachitaensis, Bolivina caucasensis, Nonion rotulum, Anomalina hantkeni, A. granosa, Cibicides perlucidus* were detected in these sediments. The thickness is 60 m.

In the Khilmilli section, the deposits of the *Globigerina officinalis* zone lie over the *Globigerina corpulenta* zone conformably. *Cibicides* ex. gr. *lobatulus, Glomospira charoides, Globigerina officinalis, G. eocaena, Eponides praeumbonatus, Hastigerina micra, Bolivina antegressa* were distributed in sandstone interlayers within gray, green, and reddish-brown

clays (up to 20 m thick) in the sediments related to this zone.

The Oligocene. The Rupelian stage. The Oligocene deposits make up the lower part of the Maykop deposits in the Southeastern Caucasus.

The deposits of the Rupelian stage conformably lie over the Priabonian deposits in the Khilmilli section. *Globigerina tumbeli* zone was distinguished in these deposits. The deposits of the described zone are characterized by gray, greenish-gray, and dark gray thin clay layers. Yarosite and Manganese oxide layers are observed on these clays. These clays are characterized by the presence of *Globigerina tumbeli, Glomospira charoides, Ammodiscus incertus, Ammosphaeroidina caucasica, Nonion pseudomartkobi, Bolivina dentalata, Nodosaria inexculta, N. capitata.*

Bionomy of the basin

The Southeastern Caucasus developed under an independent and distinct geotectonic condition. During the Paleogene period, volcanic activity occurred at different times with varying intensity across different regions. The Eocene, particularly the Middle Eocene basins had distinct paleogeographic landscape and bionomic condition in the regions of Azerbaijan. Products of intermittently submarine-erupting volcanoes in various areas played a significant role in sedimentation processes, in the modification of basin parameters, and in some regions, in the deterioration of its ecological conditions. Since geological events occurred with different intensities across regions, the species and genus composition of biotas, as well as the number of their individuals varies significantly on areas (Babayev və b., 2015).

During the Paleogene period, light-colored clays, minor clay-carbonate mixtures, and sandy sediments were deposited in the basin in the Southeastern Caucasus. Benthic and planktonic foraminifera were widely developed in the basin, whereas conditions were unfavorable for macrofauna. During the Paleogene period, the development of the microfauna of Azerbaijan proceeded in four distinct stages: The Paleocene–Early Eocene, The Middle Eocene, The Late Eocene, and The Early Oligocene. Changes in the composition of complexes and foraminiferal morphology were observed throughout these stages (Герасимов, Мещеряков, 1964).

During the Lutetian stage of the Middle Eocene, the part of the Upper Koun and the lower layers of the Middle Koun, and during the Bartonian age, the lower part of the Middle Koun and the Upper Koun were deposited in the basin in the South-Eastern Caucasus. When the Koun formation was deposited in basin, bionomic conditions began to recover. The rhythmic alternating layers of the Koun formation are thicker compared to Paleocene rhythms. It can be assumed that the sea depth also decreased slightly. As a result of these changes, no fauna other than benthic and planktonic microfauna developed in the basin (Bağmanov, 2005).

Conclusions

Based on researches carried out in the Khilmilli section of the Gobustan region in the South-Eastern Caucasus, the following results were obtained:

– The stratigraphic subdivision of the Paleogene deposits was established using the rich foraminiferal assemblages identified from the samples collected in the Khilmilli section. It was determined that the Khilmilli section contains rocks belonging to the Paleocene, Eocene, and Oligocene series. In particular, deposits corresponding to the Danian and Thanetian (Paleocene), Ypresian, Lutetian, Bartonian, and Priabonian (Eocene), as well as the Rupelian (Oligocene) stages are present. At the same time, deposits of the Selandian stage were not detected within the section.

– A zonal subdivision of planktonic foraminifera within the Paleogene deposits was presented. The distribution of foraminifera across the zones was traced, and their evolutionary development was described. The complex composition of zones and changes observed within them were thoroughly interpreted. In addition, comprehensive data on the bionomy of the basin was provided.

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КОМПЛЕКС МИКРОФАУНЫ ПАЛЕОГЕНОВЫХ ОТЛОЖЕНИЙ И РЕКОНСТРУКЦИЯ БИОНОМИИ БАССЕЙНА НА ОСНОВЕ РАЗРЕЗА ХИЛЬМИЛЛИ В ГОБУСТАНСКОМ РАЙОНЕ ЮГО-ВОСТОЧНОГО КАВКАЗА

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Резюме. Статья посвящена биостратиграфическому расчленению палеогеновых отложений Юго-Восточного Гобустана. Расчленение выполнено на основе материалов, полученных из разреза Хильмилли. По образцам, отобранным в данном разрезе, проведены исследования фораминифер. Стратиграфическое подразделение палеогеновых отложений изучаемой территории детально обосновано по данным фораминифер и прослежено по всему разрезу Хильмилли. На основе богатых ассоциаций фораминифер в разрезе установлено подробное деление палеогеновой толщи на этажи и зоны. Микрофаунистические данные позволили разделить палеогеновые отложения на палеоценовый, эоценовый и олигоценовый отделы и их стратиграфические подразделения. Установлено, что в разрезе Хильмилли присутствуют породы датского и танетского (палеоцен), ипрского, лютетского, бартонского и приабонского (эоцен), а также рупельского (олигоцен) ярусов. Прослеживание микрофауны по разрезу позволило точно интерпретировать комплексный состав зон и изменения, происходящие в их пределах. Выявлено распределение фораминифер по зонам и описано их развитие по стратиграфическим уровням. В то же время в разрезе не обнаружены отложения зеландского яруса. В работе также приведены обоснованные сведения о биономии бассейна.

Ключевые слова: *Фораминиферы, фауна, палеоцен, эоцен, олигоцен, планктон, бассейн, палеоген, микрофауна*

CƏNUB-ŞƏRQİ QAFQAZIN QOBUSTAN VİLAYƏTİNDƏ PALEOGEN ÇÖKÜNTÜLƏRİNİN XİLMİLLİ KƏSİLİŞİNDƏ KOMPLEKS MİKROFAUNASI VƏ ONA ƏSASƏN HÖVZƏ BİONOMİYASININ BƏRPASI

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Xülasə. Məqalə Cənubi-Şərqi Qobustanın Paleogen şöküntülərinin biostratiqrafik bölgüsünə həsr edilmişdir. Bölgü Xilmilli kəsilişindən götürülmüş materiallar əsasında aparılmışdır. Kəsilişdən götürülmüş nümunələrin əsasında foraminiferlərin tədqiqatı aparılmışdır. Tədqiq olunan ərazidə Paleogen çöküntülərinin stratiqrafik bolgüsü ftoraminiferlərə görə ətraflı əsaslandırılmış və Xilmilli kəsilişində izlənilmişdir. Kəsilişdə Paleogen çöküntülərinin zəngin foraminifer assosiasiyası əsasında mərtəbə və zonal bölgüsü verilmişdir. Paleogen çöküntüləri mikrofauna vasitəsilə Paleosen, Eosen və Oliqosen şöbələrinə və mərtəbələrə bölünür. Müəyyən edilmişdir ki, Xilmilli kəsilişində Danimarka, Tanet, (Paleosen) İpr, Lütet, Barton, Priabon (Eosen), Rupel (Oliqosen) mərtəbələrinin süxurları iştirak edir. Kəsiliş üzrə mikrofaunanı izləməklə zonaların kompleks tərkibi və onlardakı dəyişikliklər dəqiq şərh edilmişdir. Foraminiferlərin zonalar üzrə paylanması izlənmiş və onların mərtəbələr üzrə inkişafı təsvir edilmişdir. Eyni zamanda kəsilişdə Zeland mərtəbəsinin çöküntüləri aşkar edilməmişdir. Hovzənin bionomiyası haqqında da əsaslı məlumat verilmişdir.

Açar sözlər: *Foraminiferlər, fauna, Paleosen, Eosen, Oliqosen, plankton, hovzə, Paleogen, mikrofauna*

Stratigraphy, petroleum sedimentology, geochemistry **2 / 2025**

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PALEOMAGNETIC STUDY OF ANDAMICH, AZA AND DIZA SECTIONS (NAKHCHIVAN, AZERBAIJAN)

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Summary. In the paper, the results of the study of Paleogene sediments in the territory of the Nakhchivan Autonomous Republic, the horizontal movements of the Earth's crust, and the solution to the problem are given. Paleomagnetic studies were carried out in two transects, Aza and Andamich, and Paleogene sediments were studied. Initially, the kinematic parameters and horizontal movements of the blocks are determined based on the paleomagnetic data. The discussion of the results of the paleomagnetic research conducted in the territory of the Nakhchivan Autonomous Republic was carried out on rocks of the Paleogene age.

Similar results were obtained while characterizing the components of I_n: clays, fine-grained sandstones are more stable, coarser-grained rocks are metastable, and coarse-grained sandstones, marls, siltstones, etc., are unstable. On average, they have the same direction as the magnetization direction, as determined by the cross-sectional method.

The sections show a regular alternation of rocks with direct and reverse magnetization. After temporary and temperature cleaning, as well as alternating magnetic cleaning, in the Aza and Andamich sections, both directly and reversely magnetized rocks have the same direction. All this indicates the synchronism of I_n^o and the absence of the secondary magnetization components in I_n after cleaning. The relevance and importance of the paleomagnetic studies conducted are also noted; only through this method is it possible to determine the paleotectonic positions and quantitatively assess the rotations of certain geological structures on others.

Keywords: *Magnetic susceptibility, stratigraphic division, geological-geophysical analysis of the Ordubad synclinorium, Andamich sections, Paleocene epoch*

Introduction

This paper reviews the stratigraphic and paleomagnetic studies in the Aza and Andamich sections of the Ordubad synclinorium in Azerbaijan. The stratigraphic sequence of the sediments filling the depression is considered. Particular attention is paid to the discussion of controversial issues and problems of stratigraphic division and determination of the age of stratigraphic units. The results of paleomagnetic studies of the Cenozoic sediments of the basin are summarized. The most promising objects of the detailed paleomagnetic studies are indicated. The studied Paleogene sequences at the Aza and Andamich sections are represented by volcanic-sedimentary and sedimentary rocks (Babayev və b., 2016).

The Andamich section represents the Danish Stage and the Paleocene from bottom to top. The thickness of this stage in this section is 361 m. When compiling general and regional paleomagnetic scales, it is necessary to obtain a better understanding of the nature of the change in the geomagnetic field over time and estimate the age of magnetic units. Paleomagnetic studies were therefore carried out using methods generally accepted in rock magnetism and paleomagnetism (Исаева и др., 2019).

The section of the Danian stage and Paleocene deposits along the northeastern Aza anticline (northwest of the village of Sabirkand at 943.4 m) are presented from bottom to top. The thickness of the Paleocene and Danian stages of the Aza section is 414 m. In most cases, the oriented samples were selected along the section; the sampling interval depended on the thickness of the section and the composition of the outcrop rocks (Fig. 1). This was necessary to obtain

the most objective data on the magnetic parameters of the considered massif. When selecting a sample, preference was given to the central part of the body, since they are less changed (Исмаил-заде и др., 2005).

Geology of the studied area

The geological structure of the Nakhchivan Autonomous Republic includes deposits of the Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Paleogene, Neogene, and Quaternary systems (Исаева и др., 2019).

Formations of the Paleocene section were detected in the river basins of Chahrichay and Nakhchivanchay as well as along the left riverbank of Araz between the towns of Julfa and Ordubad (Fig. 2). They mainly consist of the sedimentary formations of the Lower (Danian), Middle (Selandian), and Upper (Thanetian) Paleocene periods with an average thickness of 670 m and a generalized maximum thickness of 1.120 m.

The upper part of the Danish tier is located near the village of Aza. This formation is composed of a pack of gray carbonate thin-layered sandstones, with rare interlayers of sheet clay measuring 50-55 meters in thickness.

Foraminifera are found *Acarinina schakhdagica, A. tridadensis, A. spirialis, A. trifida, A. inconstans, Globigerina varianta, G. legitima, G. guadrata, G. triangularis* – nanoplankton – *Placozygus sigmoides, Chiasmolithus californicus, Ellipsolithus macellus, Cyclococcoolithus* sp.

In most cases, the oriented samples were selected along the section; the sampling interval depended on the thickness of the section and the composition of the outcrop rocks. This was necessary to obtain the most objective data on the magnetic parameters of the considered massif. When selecting a sample, preference was given to the central part of the body, since they are less changed (Халафов и др., 1996).

1. Alternation of gray thin and medium argillite (0.1-0.5) and sandstones (0.05-0.3 m). In the composition of argillites, *Globoconusa daubjergensis* (Bronniman), *Globigerina triloculinoides* Plummerand other foraminifera have been discovered.

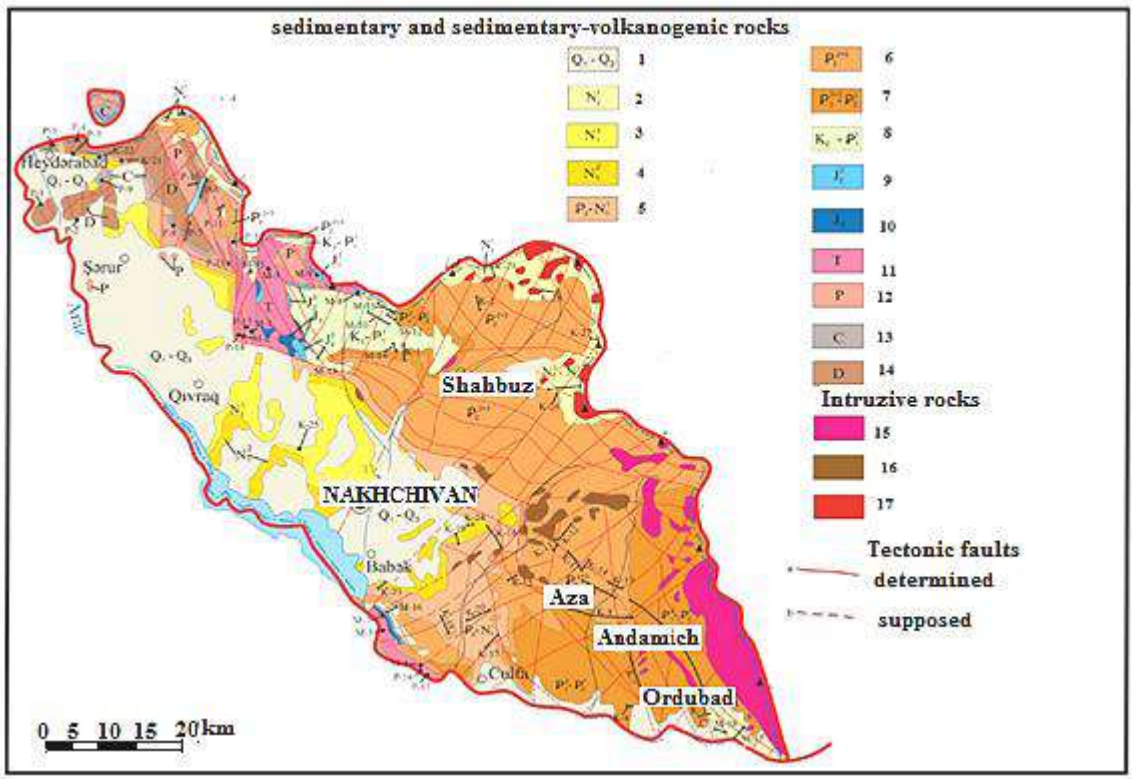

Fig. 1. Geological map of Nakhchivan Autonomous Republic (T.N.Kangarli)
1 – Pleistocene, **2** – Lower Pliocene, **3** – Upper Miocene, **4** – Middle Miocene, **5** – Oligocene and Lower Miocene, **6** – Middle and Upper Eocene, **7** – Middle Paleocene and Lower Eocene, **8** – Upper part of the Upper Cretaceous (Cenomanian) and Lower Paleocene, **9** – Middle Jurassic, **10** – Lower Jurassic, **11** – Triassic, **12** – Permian, **13** – Carbonian, **14** – Devonian, **15** – Eocene-Oligocene, **16** – Miocene, **17** – Lower Pliocene

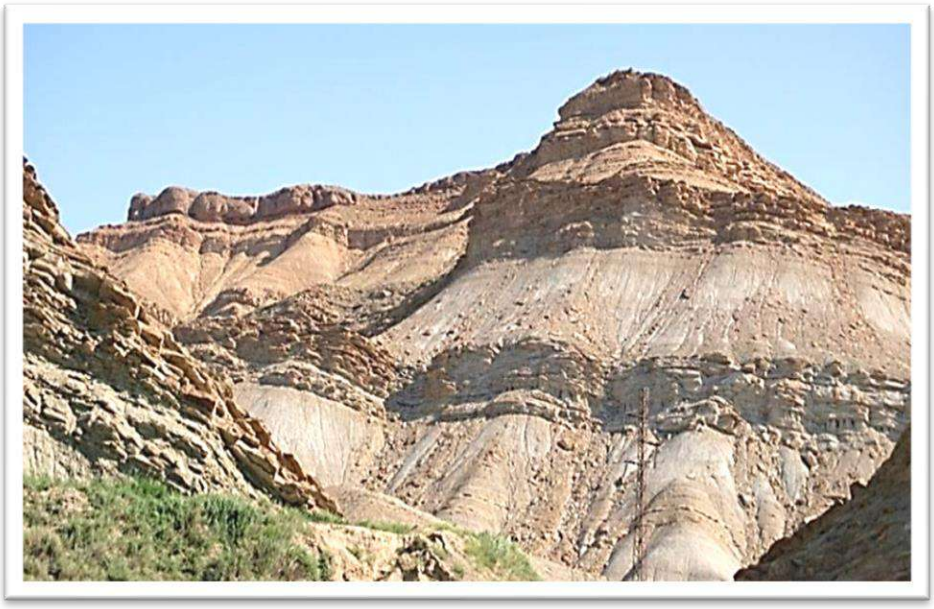

Fig. 2. Discovery of the Aza Deposit from the Lower Paleocene Period

2. Soft argillites of a gray, reddish hue (0.25-2.0 m), alternating with layers of fine-grained sandstone, foraminifera typical of the Danian age were found in argillites of the lower part of the layer *Acarinina trifida* Chal., *A. inconstans* (Subb.), *A. constans uncinata* (Bolli), *Globigerina trivialis* Subb., and *G. varianta* Subb.

3. Frequent alternation of gray-colored, thin- and medium-sized soft argillite, fine-grained calcareous sandstone, and calcareous sandstones. Argillites predominate. In the middle part of the layer the foraminifera of the Danian age were found in argillites: *Acarinina trifida* Chal., *A. inconstans* (Subb.), *A. constans uncinata* (Bolli), *Globigerina trivialis* Subb., and *G. varianta* Subb.

4. Alternation of thin and medium-layered argillite dense, sheet-shaped finegrained sandstones of gray color. *Acarinina inconstans inconstans* (Subb.), *Globigerina trivialis* Subb. The thickness of the Aza layer in the described cross section is 493 m. (Babayev və b., 2016).

Methodology

Samples were taken in the area from Aza to Diza, where paleomagnetic studies were conducted. Magnetic susceptibility k was measured in the field and in the laboratory using a KT-5 kappometer (Czechia) with a sensitivity of 10^{-5} CGS. Under laboratory conditions we determined initial residual magnetization by measuring demagnetization in samples with variable and constant magnetic field by measuring with modern Spinmagnetometer JR-6A, AGICO LDA-5 TD-48-SC Thermal Demagnetizers thermal cleaning furnace (temperature demagnetization) devices (Bagirova et al., 2023) Spinmagnetometer JR-6A, production of Agico, Czech Republic. It is used to measure the residual magnetization of rock samples, especially strong magnetic samples. The principle of operation of this device consists in measuring the phase and amplitude of the changing force of electric motion. The TD-48-SC thermal cleaning furnace (temperature demagnetization) unit is designed for temperature demagnetizing of rock samples, as well as for creating thermal uniformity in a small fixed area. Temperature range: 25-800ºC.

LDA-5 Demagnetizer. This device measures the demagnetization of a sample with a variable and constant magnetic field. The demagnetization process is controlled and automated by a microprocessor. It is enough to set the demagnetization parameters, mark the sample in the sample holder, and place the retainer on the demagnetization coil. The rest of the demagnetization process is performed automatically according to the preset parameters (Молотовский, 1985). The technique of selecting the oriented samples and their documentation was carried out according to standard methods for paleomagnetic studies. Rock samples were

selected from each unit. The samples were given a cubic shape of 24x24 mm. The main issue in all paleomagnetic studies is the question of the primacy of the natural residual magnetization of the studied rock. For the primary residual magnetization arising at the time of rock formation to retain its original value and direction until the time of study, it must be stable in the face of various destructive effects.

Natural residual magnetization of rocks consists of two main components: primary, synchronous with the process of rock formation, and secondary, which arises after formation of the primary signal (Исмаил-заде и др., 2005). To isolate the viscous residual magnetization I_{rv}, we attempted to determine its prevalence and correct the associated error in the samples left for measurement. In the laboratory, the samples were influenced by the Earth's magnetic field for two weeks in the position in which they were in situ in the field. In this case, their viscous magnetization is restored. After temporary cleaning, the half-differences of both values give the viscous component of the residual magnetization in the samples.

Results

The field and laboratory paleomagnetic studies of the Paleogene rocks of Nakhchivan made it possible to determine the directions of I_n, to prove the nature of the initial residual magnetization and the synchronicity of these rocks with the time of their formation. On the basis of these studies, paleomagnetic zones of flat and reverse polarity were identified. These zones can be considered reliable since they are represented by more than 60 samples taken from different stratigraphic levels and traced in cross-sections of the same age at a distance from each other. Paleocene rocks collected in the Aza and Andamich river basins do not differ much in magnetic properties. Paleomagnetic data obtained from the Paleogene sediments of the Nakhchivan Autonomous Republic provide data on the nature of the Earth's magnetic field in the studied areas and tectonic movements in the Paleocene and Eocene (Храмов, Шолпо, 1967).

The direction of primary residual magnetization in the studied rocks indicates a sharp difference between the direction of the Paleocene and Eocene magnetic field and the modern field. Comparing these data, the kinematic parameters of local and regional rotation of the entire region were determined (Bagirova, Rzayev, 2018).

Field and laboratory paleomagnetic studies of the Paleogene rocks of Nakhchivan made it possible to determine the directions of I_n, to prove the nature of the initial residual magnetization and the synchronicity of these rocks with the time of their formation. On the basis of these studies, paleomagnetic zones of flat and reverse polarity were identified (Халафлы, 2007).

Discussions

In order to isolate the viscous residual magnetization I_{rv}, we tried, on the one hand, to determine how widespread it is and, on the other hand, to correct the associated error on samples left for measurements. In the laboratory, the samples were exposed to the Earth's magnetic field for two weeks while maintaining their in situ position. In this case, their viscous magnetization is restored (see Fig. 3) (Исаева и др., 2019).

It is possible to easily determine magnetic minerals in the composition of rocks by the Curie temperature by the magnetic method. Ts=585º due to its mineralogical composition, maghemite is distinguished from magnetite with great difficulty. The lattice constant of the maghemite is smaller than that of magnetite. Due to the fact that it is not resistant to heating, it oxidizes and passes to hematite; it is very convenient to apply the magnetic method for its determination. The transition of the main part of maghemite to hematite occurs at the limit of 250-450º. This phase transition is observed with a decrease in the saturation magnetization of I_{rs} and an increase in H (Fig. 2) (Баженов, 1983).

After temporary cleaning, the half-differences of both values give the viscous component of the residual magnetization in the samples (Халафлы, 2007). The Paleocene and Danian deposits are represented by greenish-gray calcareous clays and sandstones. In these samples, magnetic susceptibility k varies within 6-7•10-3 SI units, and the value of residual magnetization I_n fluctuates within 4-8•10-3 SI units. In the Andamich section, the Q factor varies within 15-33, and in the Aza section, it is 1.6-2.0.

Thermal cleaning gives similar results. The natural residual magnetization of most samples decreases at a temperature of 100-150ºC to an average of 0.8-0.7, and at temperatures of 250-300ºC to 0.4-0.2 of the initial value, while the directions remain the same, probably close to the direction of the primary magnetization (Bagirova et al., 2023).

For samples collected near the villages of Aza and Andamich, it is possible to find the direction of primary magnetization using the method of intersection of remagnetization planes. For the Aza village section, the normal polarity specimens have a Fisher mean direction of: D=328º, J=44º, K=12, α_{95}=10º. The reverse polarity samples has a Fisher mean of D=142º, J=-45º, K=11, α_{95}=12º. For Andamich village section the normal and reverse mean directions are D= 97º, J=32º, K=3, α_{95}= 11º; D=106º, J=54º, K=5, α_{95}=16º. In the sections, a regular alternation of rocks with normal and reverse polarity magnetization is observed: for the Aza section, the sample means of k=1.75x10^{-6} SI units; and I_n are 10.09 x10^{-9} A/m, and for the Andamich section are k=0.5x10^{-6}SI units; I_n=8.7 x10^{-9}A/m (Tables 1, 3).

The rocks in the Aza and Andamich sections include hematite as the remanence carrier (Table 2).

Table 1

Primary paleomagnetic directions and paleomagnetic poles of the Paleogene rocks of Nakhchivan.
P=Paleocene, E=Eocene, N=number of samples, D=declination, J=inclination, K=Fisher K,
α_{95}=virtual geomagnetic pole (VGP) 95% cone of confidence

Sections	**N**	**Age**	**Latitude/longitude**		**Field directions**				**VGP**	
			φ	λ	D	J	K	α_{95}	Φ	Λ
Aza	41	P	38.9	45.8	42	45	11	7	53	142
Andamich	19	P	38.9	46.01	36	54	5	14	61	133
Julfa	32	E	39.2	45.6	341	33.5	11	8	63	269
Shahbuz	51	E	39.4	45.57	33	47	10	6	60	147
Diza	27	P	38.9	45.87	29	35	5	13	58	165

Table 2

Mineral content (%), based on X-ray diffraction

Sample name	**SiO_2**	**$CaCO_3$**	**Fe_2O_3 hematite**	**Others**
Andamich-200	12	54	4	Dolomite 5
Andamich-211	20	30	6	Dolomite 5
Andamich -219	20	25	9	Dolomite 7

Table 3

Chemical composition of minerals of rocks of the Danian-Paleocene formations of Nakhchivan

Sample	**TiO_2**	**MnO**	**Fe_2O_3**	**BaO**	**SrO**	**Cr_2O_3**	**Cl-**	**YTİ**
Andamich-200	0.62	0.08	4.47	0.01	0.12	0.0101	0.02	30.28
Andamich-211	0.92	0.13	6.44	0.13	0.07	0.0201	0.06	18.31
Andamich-219	0.72	0.18	9.99	0.02	0.05	1.8901	0.08	14.77
Shahbuz-10	0.54	0.14	4.02	0.50	0.09	0.0087	0.01	12.73
Shahbuz-13	0.46	0.10	4.84	0.09	0.07	0.0003	0.03	4.79
Shahbuz-28	0.65	0.12	6.01	0.09	0.15	0.058	0.01	14.59
Shahbuz-31	1.28	0.11	7.96	0.02	0.08	0.01	0.01	12.66
Aza-302	0.15	0.10	0.99	0.03	0.15	0.003	0.01	40.12

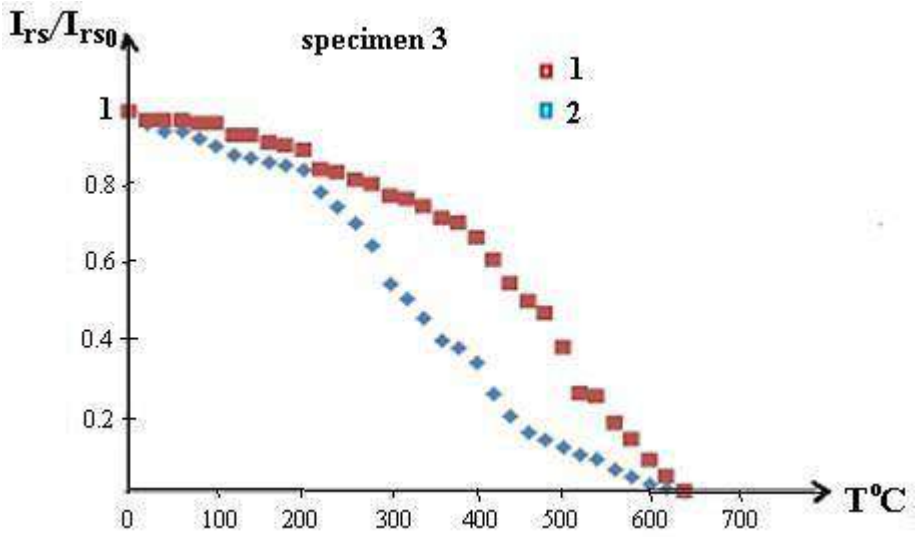

Fig. 2. Thermomagnetic analysis

The deposition dates and Paleocene in the Andamich (NAR) sections have close average values: k=0.5•10^{-6}SI units; I_n=1.75•10^{-6} SI units.

Thermal cleaning gives similar results. The natural residual magnetization of most samples decreases at a temperature of 100-150ºC to an average of 0.8-0.7, and at temperatures of 250-300ºC to 0.4-0.2 of the initial value, while the directions remain the same, probably close to the direction of the primary magnetization (Храмов, 1967).

Thermomagnetic analysis. When samples are heated to 600º, inflexions in the I_{rs}/I_{rs0} curves are detected (most often in the range 225-275º), which are not detected during reheating. After the first heating, there is no further noticeable increase (I_{rs2}/I_{rs1}=1.1-1.6 after the first and second heating), indicating the increase in I_{rs} after the first heating is associated with the decay of titanomagnetite and the release of pure magnetite (Bazhenov, 2002).

The inflection between 300 and 400ºC is not detected during further heating, which suggests this relates to a phase or phases that are not stable to heating. I_{rs} decreases after the first heating by 20-30%, indicating that the chemical transformations occurring during heating are oxidizing any newly generated or original iron hydroxides during the heating cycles (Heslop, Roberts, 2016). Some samples contain small amounts of hematite with Curie temperatures above 580ºC. These samples, which belong to the Upper Eocene deposits of Nakhchivan, are from red-colored tuffaceous sandstones. Thus, the stability to heating differs between the Eocene and Paleocene rocks (Fig. 3).

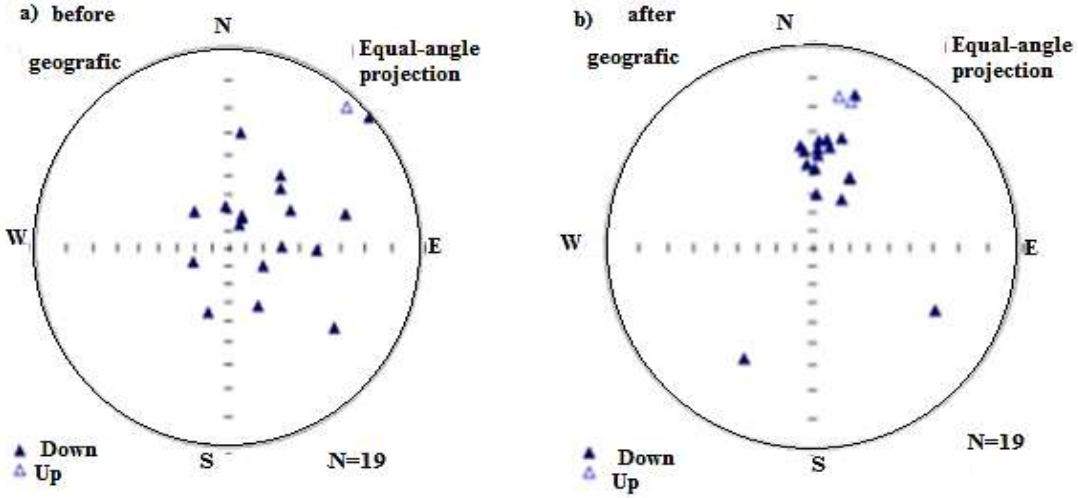

Fig. 3. Distribution of sediment rocks of the Paleocene Period

After cleaning of magnetizations, in the Aza and Andamich sections, both normally and reversely magnetized rocks have near antipodal directions (Fig. 3). This indicates the primary nature of the magnetization and the low impact of the secondary magnetization components after cleaning (Babayev və b., 2016).

The Julfa, the Diza section, the Julfa section, and Shahbuz areas were also explored, where there is a more secure link to the geologic timescale providing sections that are currently complete and well exposed. For the Paleocene–Lower Eocene located in the Nakhchivan Autonomous Republic, there are two magnetozones at Diza, with the youngest magnetozone of normal polarity corresponding to the Lower Eocene, and six magnetozones in the Paleocene: 3 zones of normal polarity and 3 zones of reverse polarity. In the Julfa River, this interval is represented by the Middle and Upper Eocene. According to paleomagnetic data, 4 magnetozones have been identified: 2 zones of normal polarity and 2 zones of reverse polarity, with the latter magnetozone of normal polarity corresponding to the Middle Eocene. The Aza section is represented by 3 magnetozones: 2 of normal and 1 of reverse polarity (Fig. 5).

The Aza and Andamich sections are represented by the Danian tier, while the N zones are distinguished by direct magnetization at the bottom of the tier on the border with the upper chalk (Heslop, Roberts, 2016). The power in section Aza is over 100 meters, and in section Andamich, it is 80 meters. In the context of Aza 2R, zone 2N, and Andamich 3R – zone 2N, there is a good convergence of poles of Azerbaijan with those of neighboring regions such as Georgia, Armenia, Turkmenistan, and Tajikistan (Fig. 4) (Fig. 4.1).

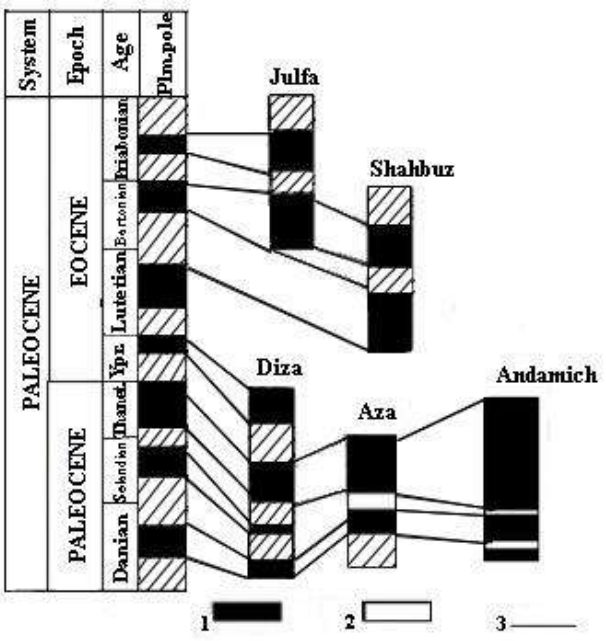

Fig. 4. Magnetostratigraphic sections of the Paleogene of the Nakhchivan Autonomous Republic
1 – zone of reverse magnetization; **2** – zone of direct magnetization; **3** – correlation lines

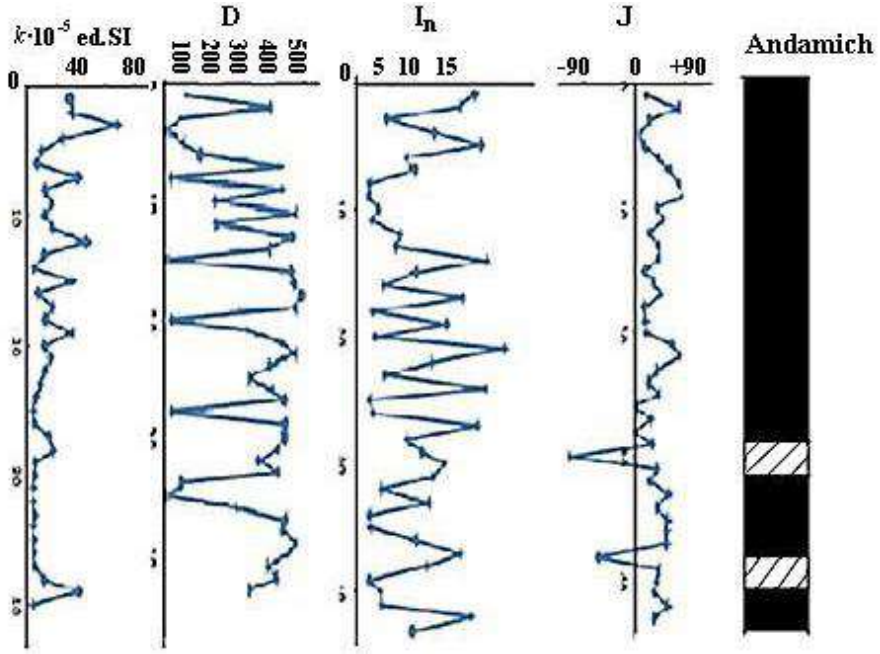

Fig. 4.1. Paleomagnetic section of continental Paleogene sediments of Andamich section

The direction of primary residual magnetization in the studied rocks indicates a sharp difference between the direction of the Paleocene and Eocene magnetic field and the modern field. Comparing these data, the kinematic parameters of the local and regional rotation of the entire region were determined. During the Paleocene epoch, the Diza section, located at the 34º paleolatitude, moved northwards at a velocity of 500±30 km/year, equivalent to 3.0-3.1 cm/year.

The Diza block rotated 29º degrees clockwise, respectively, and the Aza part, located at the 33º paleolatitude moved northwards at a velocity of 600±30 km/year, equivalent to 3.2-3.3 cm/year. The Aza block turned clockwise, respectively, 200º back.

During the Eocene epoch (23 Ma), the Diza section, located at a paleolatitude of 35º, shifted northward by 500±300 km with a translational motion rate of 2.3-2.5 cm/year.

The Diza section block rotated 34º counterclockwise, while the Julfa section, at a paleolatitude of 35º migrated northward by 500±300 km at a translational motion rate of 2.3-2.5 cm/year. The Julfa section block rotated 19º counterclockwise.

During the Eocene (41 Ma), the Shahbuz section located at a paleolatitude of 34º, moved northward by 500±30 km at a translational motion rate of 2.4-2.5 cm/year.

Conclusions

The paper presents the results of studying Paleogene deposits in the Nakhchivan Autonomous Republic, horizontal movements of the Earth's crust, and the solution to the problem. Paleomagnetic studies were carried out on two sections—Aza and Andamich—and Paleogene deposits were also studied. Initially, the kinematic parameters and horizontal movements of the blocks were determined based on paleomagnetic data. The results of paleomagnetic studies conducted on the territory of the Nakhchivan Autonomous Republic were discussed on rocks of the Paleogene age. Similar results were obtained in the characterization of the I_n-components: clays and fine-grained sandstones are more stable, coarse-grained rocks are metastable, coarse-grained sandstones, marls, siltstones, etc. are metastable. During magnetic purification, permanent magnetization components are isolated, which have on average the same directions as the pre-folded magnetization determined by the cross-sectional method. This indicates the predominance of the stable I_n-component in the studied rocks.

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ПАЛЕОМАГНИТНОЕ ИССЛЕДОВАНИЕ РАЗРЕЗОВ АНДАМИЧ, АЗА И ДИЗА (НАХЧЫВАН, АЗЕРБАЙДЖАН)

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Резюме. В статье приводятся результаты изучения палеогеновых отложений на территории Нахчыванской Автономной Республики, горизонтальных движений земной коры и пути решения проблемы. На двух разрезах, Аза и Андамич, были проведены палеомагнитные исследования и изучены палеогеновые отложения. Первоначально на основе палеомагнитных данных были определены кинематические параметры и горизонтальные перемещения блоков. Обсуждение результатов палеомагнитных исследований, проведенных на территории Нахчыванской Автономной Республики, проводилось на горных породах палеогенового возраста.

Аналогичные результаты были получены при характеристике компонентов I_n: глины, мелкозернистые песчаники более стабильны, более крупнозернистые породы метастабильны, а крупнозернистые песчаники, мергели, алевролиты и т.д. нестабильны.

Во время магнитной очистки фиксированные компоненты намагниченности изолируются. В среднем их направление совпадает с направлением намагниченности, определяемым методом поперечного сечения.

На разрезах наблюдается регулярное чередование пород с прямой и обратной намагниченностью. После временной и температурной очистки, а также попеременной магнитной очистки на разрезах Аза и Андамич как непосредственно, так и обратно намагниченные породы имеют одинаковое направление. Все это указывает на синхронность I_n^o и отсутствие компонентов вторичного намагничивания в I_n после очистки.

Актуальность и важность проводимых палеомагнитных исследований также подтверждается тем, что только с помощью этого метода можно определить палеотектоническое положение и количественно оценить вращение одних геологических структур относительно других.

Ключевые слова: *магнитная восприимчивость, стратиграфическое подразделение, геолого-геофизический анализ ордубадского синклинория, разрезы Андамич, палеоцен*

ƏNDƏMİÇ, AZA VƏ DİZƏ KƏSİLİŞLƏRİNİN PALEOMAQNİT TƏDQİQATI (NAXÇIVAN, AZƏRBAYCAN)

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Xülasə. Məqalədə Naxçıvan Muxtar Respublikası ərazisində Paleogen çöküntülərinin, yer qabığının üfüqi hərəkətlərinin və problemin həlli yollarının öyrənilməsinin nəticələri təqdim olunur. İki hissədə, Aza və Əndəmiç, paleomaqnit tədqiqatları aparıldı və paleogen çöküntüləri araşdırıldı. Əvvəlcə paleomaqnit məlumatlar əsasında kinematik parametrlər və blokların üfüqi hərəkətləri müəyyən edilmişdir. Naxçıvan Muxtar Respublikası ərazisində aparılan paleomaqnit tədqiqatlarının nəticələrinin müzakirəsi Paleogen dövrünə aid qayalarda aparılıb.

I_n komponentlərinin xarakteristikasında oxşar nəticələr əldə edilmişdir: gillər, incə dənəli qumdaşları daha sabitdir, qaba dənəli süxurlar metastabil, qaba dənəli qumdaşları, mərmərlər, lil daşları və s. qeyri-sabitdir.

Maqnit təmizlənməsi zamanı maqnitləşmənin sabit komponentləri təcrid olunur. Orta hesabla, onların istiqaməti kəsişmə metodu ilə təyin olunan maqnitləşmə istiqaməti ilə üst-üstə düşür.

Kəsilişlərdə birbaşa və tərs maqnitləşmə ilə süxurların müntəzəm dəyişməsi müşahidə olunur. Müvəqqəti və temperatur təmizlənməsindən, həmçinin Aza və Əndəmiç kəsilişlərindəki alternativ maqnit təmizlənməsindən sonra həm birbaşa, həm də geri maqnitlənmiş süxurlar eyni istiqamətə malikdir. Bütün bunlar I_n^o sinxronluğunu və təmizləndikdən sonra I_n-də ikincil maqnitləşmə komponentlərinin olmamasını göstərir.

Paleomaqnit tədqiqatlarının aktuallığı və əhəmiyyəti yalnız bu metodla paleotektonik mövqenin müəyyən edilə bilməsi və bəzi geoloji strukturların digərlərinə nisbətən fırlanmasının kəmiyyətcə qiymətləndirilməsi ilə təsdiqlənir.

Açar sözlər: *Maqnit həssaslığı, stratigrafik bölgü, Ordubad sinklinoriumunun geoloji-geofiziki təhlili, Əndəmiç kəsilişləri, Paleosen dövrü*

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MINGACHEVIR FINDSPOTS OF THE PLEISTOCENE VERTEBRATE FAUNA AND PALAEOLITHIC SITES OF HOMINID: GEOSITE OF THE GLOBAL NATURAL-HISTORICAL HERITAGE (NORTH-WEST AZERBAIJAN)

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Summary. The paper deals with results of study of the fossil vertebrates and the Lower Palaeolithic sites located in the West Azerbaijan. In Jeyranchol steppe and vicinity of Mingachevir reservoir the richest burials of vertebrates in combination with the Lower Palaeolithic sites of the Absheronian-Bakuvian time had been discovered. The sites of the fossil vertebral fauna such like Eldar, Gushguna and Bozdagh-Garaja, are rightfully evaluated as the unique geological monuments (geosites). The history of discovery and study of the described geosites and the Lower Palaeolithic sites is given as well. The detailed analysis of the fossil fauna made it possible to identify the Pleistocene mammalian species exclusive for the Caucasus. There are data regarding the paleogeographic environments of the Miocene-Pleistocene in the South Caucasus eastern part as well as the data regarding the geologic-geomorphological situation in the area of Lower Palaeolithic site Garaja. The possible time frames (Bakuvian time, 0.5-0.4 Ma) of the archaeological site forming are defined on the base of analysis of geologic setting and paleofauna remains. The analysis of archaeological materials is given. The integrated studies of the fossil fauna findspots and the Lower Palaeolithic archaeological sites had allowed reconstructing the paleogeographic conditions of habitat of the fossil fauna and early hominids during the Miocene-Pleistocene. As concluded from the studies, the surroundings of Mingachevir water reservoir represent the unique (over 100 km) "graveyard" of fossil vertebrates and the concentration of the Lower Palaeolithic archaeological sites.

Keywords: *Mingachevir reservoir, geosite, vertebrate fauna, Azykh, Garaja, Guruchay culture*

Introduction

The territory of Azerbaijan, especially the western regions, is rich with findspots of the various types of the Miocene-Pleistocene vertebrates (the findspots Eldar, Gushguna, Bozdagh, Hojashen, Guzguntapa, Palantoken, Kudbarekdagh, etc.). There are also Palaeolithic sites demonstrating all stages of the Early Stone Age since the Lower Palaeolithic Oldowan (Guruchay culture) to the Upper Palaeolithic (the caves Azykh, Taghlar, Gazma, Dashsalakhli and Damjili, as well as the open sites Gadirdere, Shishguzey, Gayali, the Jeyranchol group of sites, etc.) (Fig. 1).

In the region, the active palaeozoologic explorations of findspots containing the fossil remains of the vertebrates in the Miocene-Pleistocene coastal-marine and continental sedimentary series were carried out at different years (Burchak-Abramovich, 1950, 1952, 1954; Burchak-Abramovich and Akhundov, 1960; Hajiyev, 1959, 1996, 1999; Jafarova, 1961; Dombrovsky, 1914; Dubrovo and Burchak-Abramovich, 1984; Lebedeva, 1971; Bogachov, 1933, 1938; Eybatov et al., 2019; Hajiyev, 1959) . As a result of these studies, the rich osteological material had been collected especially within Eldar, Bozdagh and Gushguna findspots. At the same time, it was de-

termined that the region of study is the richest place in the Caucasus where the remains of the Pleistocene vertebrates of family *Elephantidae* (Bogachov, 1933, 1938; Eybatov et al., 2019; Novruzov et al., 2024). Besides it, in 1960 Burchak-Abramovich, N.I. and Akhundov, F.M. had discovered the giant camel in the Upper Absheronian sediments of Bozdagh (Burchak-Abramovich and Akhundov, 1960). That was the find of the most ancient giant camel on the territory of the former USSR.

At the same time, the searching and study of the Lower Palaeolithic archaeological sites were carried out by (Jafarov, 1999; Mansurov, 2020; Zeynalov, 2016; Huseynov, 2010). For several decades, the very early testimony of the South Caucasus settlement by early hominids was the cave Azykh in Azerbaijan. Here the lower layers VII-X contained the local culture Oldowan, defined as Guruchay culture of 1.2 Ma (Huseynov, 1979, 2010) The similar stone tools had been found in Dagestan (Amirkhanov 2013) and within Taman Peninsula in the North-West Caucasus (Kulakov, 2018). All these argue for settlement of the Caucasus uplands and foothill parts by the early representatives of genus Homo about 2 Ma ago. Back at that time the Caucasus uplands and foothill parts could be included in the single zone of accessible land between the Absheronian basin of the Caspian Sea and the Gurian basin of the Black Sea (Derevianko, 2009, 2015).

Currently, there are enough evidences confirming the present hypothesis and transformed into the science fact. In particular, these are the Lower Palaeolithic archaeological sites in the South Caucasus in Azerbaijan and Georgia (Azykh and Dmanisi accordingly), in Dagestan (Aynikab 1, Mukhkay 1 and 2, Rubas 1) and on the Taman Peninsula (Bogatyri / Sinyaya Balka, Rodniki 1 and 2, Kermek, Tsimbal) (Huseynov, 2010; Nioradze and Nioradze, 2011; Derevianko et at., 2012; Amirkhanov, 2016; Щелинский и Kulakov, 2007; Kulakov et al., 2017; Shchelinsky et al., 2010). Judging by the finds in Dmanisi, the Oldowan industry bearers in the Caucasus were the *Homo ergaster-Homo erectus* (Vekua et al., 2011; Derevianko, 2009, 2015).

Fig. 1. Location map of fossil vertebrate fauna findspots and Paleolithic archeological sites in Azerbaijan and nearby Oldovan Sites. Dash-line rectangle indicates the region of studies at Mingachevir Water Reservoir
Findspots: **El** – Eldar; **Bz** – Bozdagh; **Hj** – Hojashen; **Gsh** – Gushguna; **Pl** – Palantoken; **Gr** – Garaja; **Shm** – Shamkir, **Kd** – Kudbarekdagh. Archeological sites: (**1**) – the cave Dashsalakhli and grotto Damjili, Gadirdere, Shishguzey, Gayali, (**2**) – the Jeyranchol group of sites, (**3**) – the grotto Zar, (**4**) – the caves Azykh and Taghlar, (**5**) – Garaja, (**6**) – the grotto Khorgaya and Jymjymakh, (**7**) – the cave Buzeir, (**8**) – the cave Gazma, (**9**) – Dmanisi, (**10**) – Oldowan sites of the Central Dagestan

At the beginning of the current century, the systematic paleozoologic and archaeological studies had been started alongshore of Mingachevir water reservoir. They allowed identifying the unique Bozdagh-Garaja findspot with rich finds of bone remains of various vertebrates as well as the richest collection of the Lower Palaeolithic industry identified within the relatively small area in the Pleistocene layers (Fig. 2).

Burials of the ancient vertebrates

Eldar findspot of the Upper Sarmatian vertebrates (Hipparion fauna) had been discovered in the 10th of the last century (Burchak-Abramovich, 1950; Derevianko, 2009; Derevyanko et al., 2012; Derevianko, 2015) in the right bank of Gabirri River (Iori River) on the slopes of Ellyar-Oyugu ridge. The findspot is distinguished by exceptional richness of finds of the fossil bones of the hipparion, chalicotheres, hyena, gazelle, proboscideans, seal, turtle and various aves (Dubrovo and Burchak-Abramovich, 1984). It had been established that the formation of typical Hipparion fauna in Azerbaijan falls on the cusp of the Middle and Upper Sarmatian. At that time, the major geological events had occurred in the Caucasus that changed the paleogeographic environment. Due to the regression of Black and Caspian seas, the Caucasus Island had connected to the Western Asian land via the formed Dzirul isthmus. The Hipparion fauna had used that formed isthmus to enter the Caucasus. At the early stages of that invasion (the Middle Sarmatian beginning), when the anchitheres coexisted with the early hipparions, transitional complex of mammals was formed. Gradually, the replacement of other genera took place with formation of core of the new theriocomplex. It is testified by the mammalian bones' findspots in Iran and especially Turkey where one can trace how entirely Anchitherium fauna transits into mixed one, and later is replaced with Hipparion fauna within the Paratethys sediments of the different age.

Bozdagh-Garaja findspot of the mammals from the Absheronian and Bakuvian sediments of the Pleistocene. The paleozoologic studies were carried out by the employees of the Natural-Historical Museum of Azerbaijan National Academy of Sciences. In the course of some field expeditions they had identified the numerous remains of the proboscideans, deer, horses, bulls and rhinoceros in the Lower Pleistocene layers eroded by the shoal waters of the reservoir.

Gushguna findspot of the Upper Pliocene-Pleistocene mammals is corresponded to the sediments of Akchagilian (marine facies) and Absheronian (continental facies) regiostages in Kura and Gabirri interfluve. That transitional (from Hipparion to Equidae) fauna was characterized by the coexistence of hipparion (tridactyl horses) and a primitive monodactyl horses – *Equus stenonis*.

Fig. 2. Location of Bozdagh and Garaja findspots, and bay #5 alongshore of Mingachevir water reservoir (GoogleEarth image)

Among the other species of vertebral fauna the eggshells of ostriches, beaver-trogontherium, flat-fronted (*Elephas planifrons)* and southern elephants (*Archidiskodon meridionalis*), the Etruscan bears (*Ursus etruscus*), gazelles, ancient camels of *Paracamelus* genus, some species of rhinoceros, including *Elasmotherium* deserve mention. The skull belonging to a new genus and species of bulls (*Adjiderebos* gen. nov., *Adjiderebos cantabiles* sp. nov.), found in Gushguna findspot, also represents a special interest (Burchak-Abramovich, 1954).

Shamkir findspot of the Upper Pliocene – Pleistocene mammals. In 2012-2013 in the area of Shamkir water reservoir the fragments of lower jaw of *E. stenonis* and the molar (Pm^4) of the *A. meridionalis* had been discovered.

In 2000, the remains of three skulls, the southern elephant skeleton, and the fragments of deer antlers had been discovered in the Absheronian sediments (Pleistocene) of the northern foothill of Bozdagh Ridge. Next year it was possible to unearth nearly complete skull of the southern elephant without the lower jaw (Fig. 3). It had been determined that the found skull belonged to the adult specimen of the southern elephant with the second molar tooth of the upper jaw (molar M^2) and started replacement for the third molar tooth of the upper jaw (M^3). The molar measurements had showed that they belong to the late form the *A. meridionalis* with signs of the steppe mammoth (*Mammuthus trogontherii*), i.e. the find belongs to a transitional form of proboscideans.

Fig. 3. Skull of the *Archidiskodon meridionalis*

Since 2012, along the northern slopes of Bozdagh and Garaja ridges, there had been discovered a great accumulation of the fossil remains of large mammals (proboscideans, deers, horses and rhinoceros). In 2015 at the beach of bay #5 (see Fig. 2) (sediments of Bakuvian regiostage of the northern slope of Garaja Ridge) a big fragment of the elephant skull with molar teeth had been excavated. The skull of Rhinoceros *Diceros merki* without the lower jaw had been found and unearthed from the sandstone 80 m north of the elephants' skull. Besides it, the various materials had been collected on bone remains of the postcranial skeleton of the rhinoceros, bull, horse, noble deer and fragments of plates of teeth of the southern elephant.

M^2 morals of the elephant have narrow crown and well distinguished medial sinuses (Fig. 4). These sings (as well as other teeth properties – frequency of plates, length of a plate, enamel thickness) allow considering the finds as of the forest elephant *Palaeoloxodon antiquus* (first indicated in the territory of Azerbaijan).

Fig. 4. Isolated upper tooth of *Palaeoloxodon antiques* from the site Garaja

When studying the incomplete skull of rhinoceros, the morphological and morphometric characteristics of the teeth had allowed approximately classifying it as *Stephanorhinus* cf. *hundsheimensis* (Fig. 5).

In 2017-2019, on the northern slops of the Bozdag ridge, the following fossils had been found in Absheronian sediments: (1) – incomplete skull of a southern elephant *A. meridionalis meridionalis* with teeth transition from M^1 to M^2 (Fig. 6); (2) – isolated mammoth teeth; (3) – complete skull of rhinoceros with lower jaw (Fig. 7); (4) – separate fragments of *Equus* sp., *Cervidae* gen ind.

It had been found that according to feature complex of various teeth change dp^4, M^1, M^2, M^3, the teeth of the Late Pliocene elephants from Bozdagh are similar to those of typical

Archidiskodon meridionalis meridionalis, specific to the Late Villafranchian age of the Europe and the West Siberia.

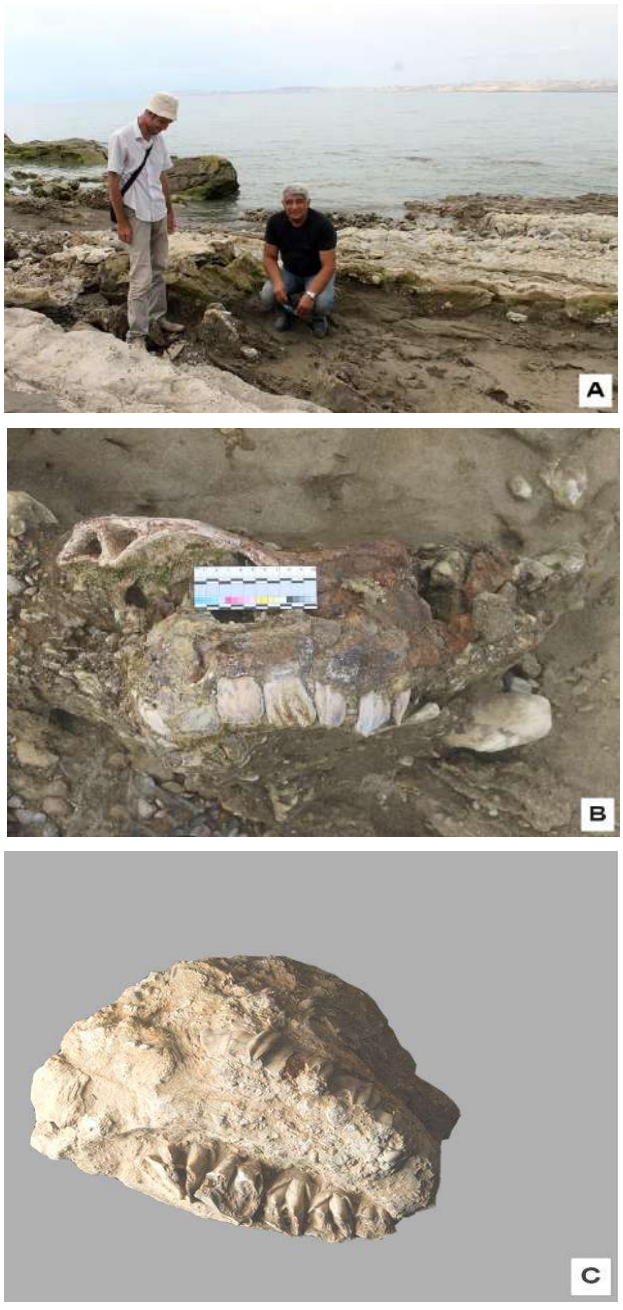

Fig. 5. Rhinoceros *Stephanorhinus hundsheimensis* from the Bakuvian sediments of Garaja site:
A place of finding; **B** teeth of the left quadrant of the upper jaw; **C** upper jaw fragment

Slightly northward, next to the mammoth skull, a fragment of antler belonging to *Praemegaceros* (the ancestor of extinct giant deer) had been found (Fig. 7).

The carried out studies had shown that Rhinoceros Diceros merki from Bozdagh (*Stephanorhinus hundsheimensis)* (Fig. 8) is the type-form for the Late Villafranchian Early Galerian of the Western Europe (analogues of Taman faunistic complex). Currently the stratigraphic distribution of this taxon in the Eastern Europe is unclear due to a fragmentary nature of earlier-defined finds of the Early Pleistocene rhinoceros within the present territory.

Fig. 6. The fragment of skull of the *Archidiskodon meridionalis meridionalis* (Bozdagh site)

Fig. 7. The antler of the ancestor giant *deer Praemegaceros verticornis*

In 2021, within Garaja area, the rich material on large mammals (elephants, rhinoceros, horses, bulls and possibly buffaloes, noble and giant deer (Fig. 9), a large fragment of the forest elephant's skull (Fig. 10), as well as very large fragment of tusk of more than 2 m long, also typical for the forest elephant, had been discovered and collected (Fig. 11). Besides it, a skull fragment of a large bovid had been excavated (Fig. 12). After restoration it had happened to be the buffalo (*Bubalus* sp.), very similar to modern Asian buffalos. Also, numerous bone fragments of bulls (*Bos* sp.) were excavated there for the first time (Figs 13, 14).

Finally, in the summer of 2022, a distal fragment of a giant deer's metapodium had been discovered in Garaja place on a flooded beach. It was the very first discovery of such kind within Mingachevir habitat area.

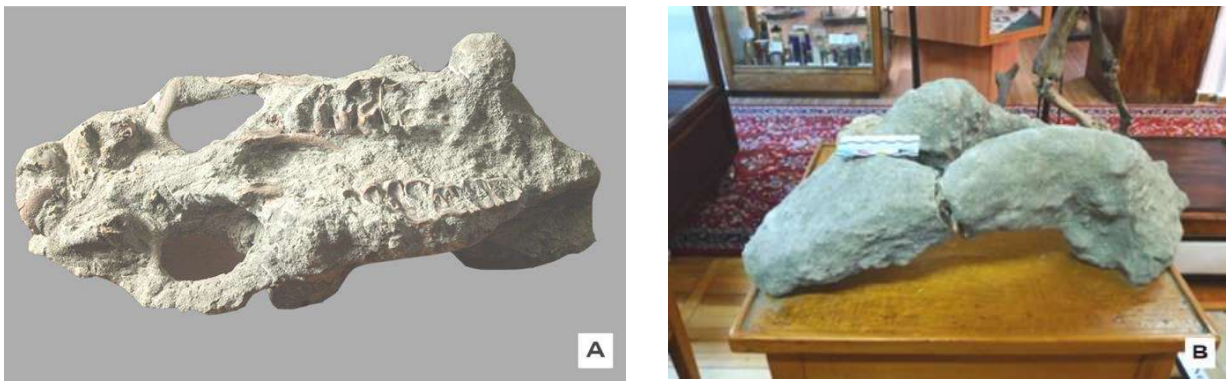

Fig. 8. Rhinoceros from Bozdagh site (*Stephanorhinus kirchbergensis*): **A** skull with upper jaw; **B** lower jaw

Fig. 9. A – The fragment of elephant teeth; **B –** deer antlers and **C** – knee joint (fragments)

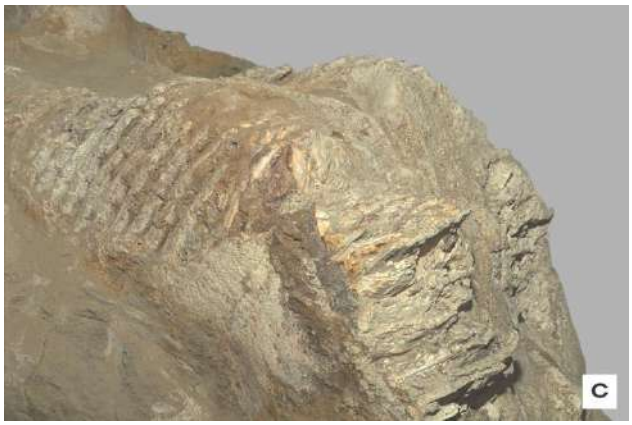

Fig. 10. Large fragment of skull with teeth *Elephas antiquus)*: **A** The process of excavation of the forest elephant's skull; **B** skull side-view; **C** dental surface top-view

Fig. 11. The forest elephant's tusk (*Paleoloxodon antiquus*)

Fig. 12. Excavation of a bull skull's fragment (field expedition of 2018)

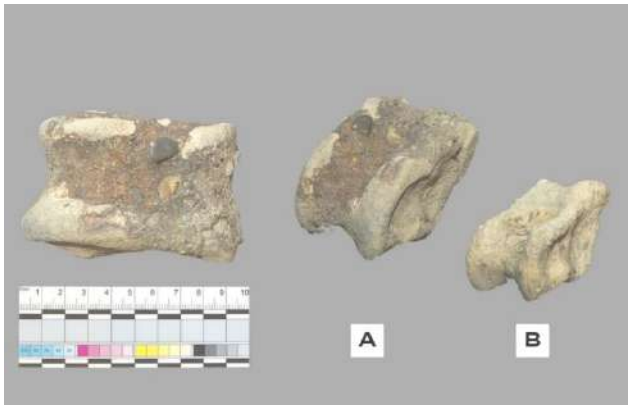

Fig. 13. A Astragali of large bulls (*Bos* sp.); **B** possibly the buffalo (*Bubalus* sp.)

Also a lot of tree remains had been found in Bozdagh and Garaja.

Along with the abundance of animal bone remains, the territory of Mingachevir habitat area is characterized by a great number of various species of the Pleistocene flora as the petrified trunks of large and small trees and shrubs. This testifies to existence in a given period of the wild animals' habitat of the region as semi-open landscapes of the forest-steppe type characterized with predominantly steppe areas alternating with tree and shrubbery vegetation.

Fig. 14. Fragments of horns and lower jaw of the bos (*Bos* sp.)

Palaeolithic findspots

Since 2012, along with the paleozoologic studies, the archaeological excavations were carried out by employees of the Institute of Archaeology, Ethnography and Anthropology of Azerbaijan National Academy of Sciences at the Mingachevir geosite. In the same year, the Lower Palaeolithic site Garaja had been discovered (Zeynalov et al., 2013). It locates in the south cost of Mingachevir water reservoir, at Bozdagh Ridge piedmont, southeastward of Garaja Mountain and 30 m above the sea level (see Fig. 1).

In the time following, some more sites had been discovered around the periphery of reservoir. Sometimes the distance between each of the discovered sites was some kilometres. Most probably, all these sites define the habitat area of Homo erectus, with the main site based in Garaja, where more than 450 closely located artefacts had been found. Without any doubt, such similar habitat areas of the primitive man existed on the banks of Kura River, which are now hidden under the waters of Mingachevir water reservoir, built in the 1950s.

At Garaja main site, two levels of palaeolithic finds had been localized at different stages of the continental deposits, subsequently overlapped by the marine sediments of the ancient Caspian Sea (Fig. 15, 16).

Fig. 15. The site Garaja. Two levels of the highest concentration of archaeological and paleontological material: (**1**) lower continental sediments: the ancient level of the artefacts, (**2**) upper continental sediments: the upper level of the artefacts. The colour dots mark the most valuable finds (for reference see Fig. 2)

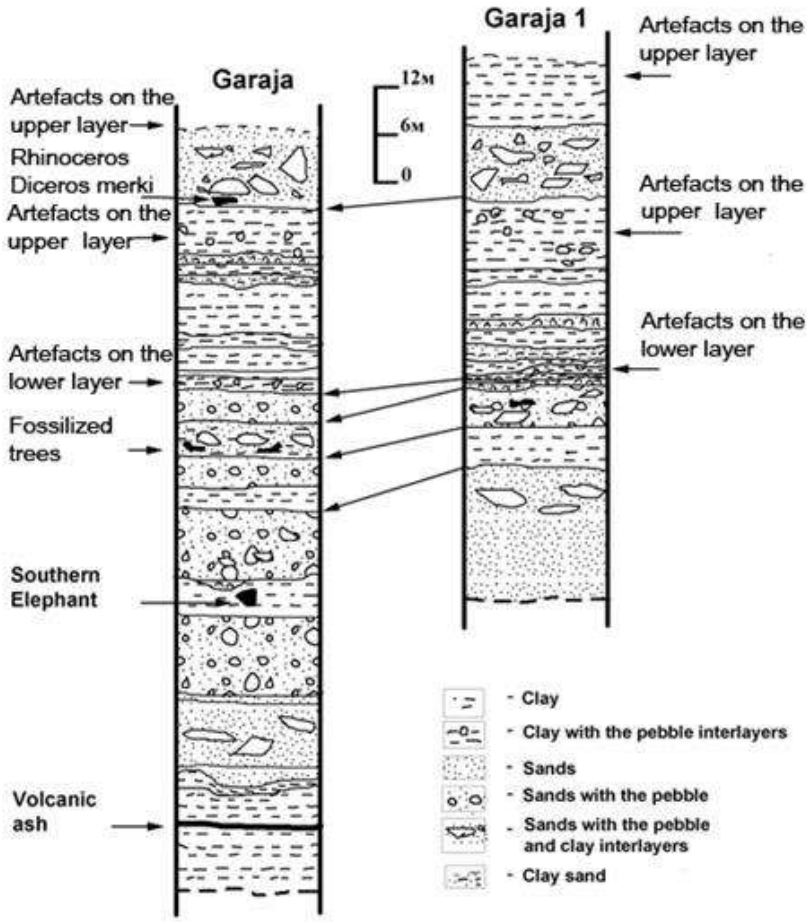

Fig. 16. The site Garaja. The sediments stratigraphy

At the piedmont, approximately 100-120 meters from the water's edge there is the lower series of the marine sediments. In the upper part of this series there is a thick bed of pink volcanic ash. Above it there is a series of continental sediments of 34-35 meters thickness. The lower level of finds is corresponded to this series.

To determine the age of sediments enclosing the rock artefacts from the site Garaja the absolute dating had been performed using the luminescent method. The absolutes date obtained for the first time for the Bakuvian sediments, show that the early settlement of the site territory took place approximately 445-460 kyr and connected with the carriers of the middle acheulian industries. This is the second half of the Marine Isotope Stage 12 and the late Bakuvian transgression of the Caspian Sea when there existed the forested multi-arm delta of proto-Kura River and the forest-steppe landscapes prevailed in the interfluve area. The second stage falls to the interval of 380-370 kyr and related with the late acheulian industries.

The collection of the lower level of finds is mainly consisted of the hand axes and choppers. Alongside these finds a unique tool had been found – the cleaver. The tool is made on a large chip of the oval pebble of the fine-grained banded rock of the brownish-grey colour (21.0 x 9.9 x 3.9-cm in size) (Fig. 17). The dorsal surface of the chip is completely covered with a cortical surface of pebbles. The distal edge of the chip – the cleaver blade – represents a natural sharp edge formed by the joint of dorsal and ventral surfaces. This distal edge remained unprocessed and has only small voids – utilization (?). The proximal edge of the chip on dorsal carries the remnants of impact surface prepared by large and medium chips to remove the chip-blank itself. Subsequently, the same impact surface had been used to refine of the impact hillock of a chip by small chips and different-sized multirow retouch. The lateral edges of the chip on the ventral surface had been carefully processed to give them straight, subparallel outline. Depending on the edges morphology, they were subjected to different treatment processes. Apparently, the ancient master aimed to gain maximally from success enough pebble chip under minimal costs for tool processing. The right edge of the chip is more straight, less processed and carefully retouched. At that time more massive left edge was almost all overwhelmed with large and small chips and retouched, but still, the master had to put two chips on a dorsal pebble surface for their straightening.

For the first time ever for the Acheulian culture in the Caucasus the tool of that kind with probable African roots had been found within Garaja findspot (Kulakov and Zeynalov, 2014). The chronological position of this tool is not yet clear, but its presence once again shows the multi-time and complex structure of Acheulian culture in the Caucasus. It seems that Caucasus during Acheulian, alike the south of France and Spain, represented one of zones of contacts and crossroads on the way of settlement to the North Eurasia of the Acheulian and earlier industries different in time and genesis.

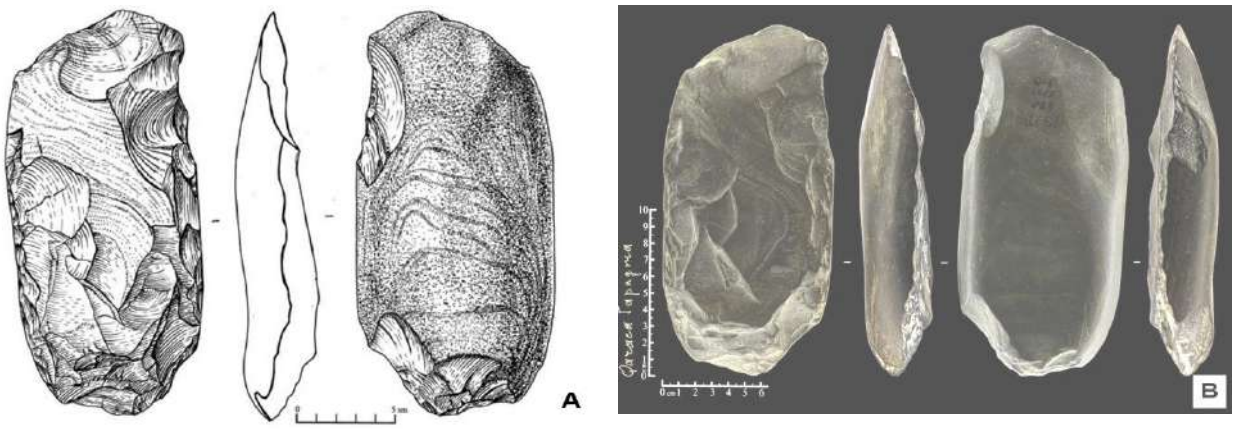

Fig. 17. Flake cleaver: **A** – graphic drawing; **B** – photo image

The earlier described upper jaw of the southern elephant (*Archidiskodon meridionalis*) with teeth had been also found in the lower continental series. Besides is, the series is rich with numerous ferruginized petrified remains trunks to 0.7 m across and up to 3-4 m in length. Up the section, there is a series of marine sediments with thickness of approximately 17 m. It is alternated by the next 40 m continental series of complicated structure. This series is mainly represented by the grey sand sequence with single interlayers of pebbles and rare tree remains. The character of their bedding indicates that they belong to stages of territory evolution and they are separated from each other by some strong erosion processes. The upper level of the finds with a gap of 15-20 meters is corresponded to this series (Idrisov et al., 2016).

In the upper level, along with choppers and beautifully designed hand axes (Figs 18, 19), the La Quina-type scraper on a large lithic flake had been found. On the same level, alongside with ferruginized trees, the bones of red deer, bull and the skull of Rhinoceros Diceros merki (see above) had been found as well.

The category of roughly-cutting tools is the richest one in collection of the lower and middle levels. Here, along with the subcategory of various choppers, there is a special subcategory of tools provisionally called “hammer-stones”. As a rule, those tools had been made from round-shaped fine-grained pebbles divided nearly into two halves. The treated edge, obtained in that manner, was carefully processing by chips and retouch all-round. The natural nodular surface had preserved at the heel that provided comfortable handy gripe. The working surface of the tool, set off against the heel, had been formed by large and small chips and retouch all-round the tool. The work edge of the tool has the utilization retouch traces nearly around the entire periphery (Fig. 20).

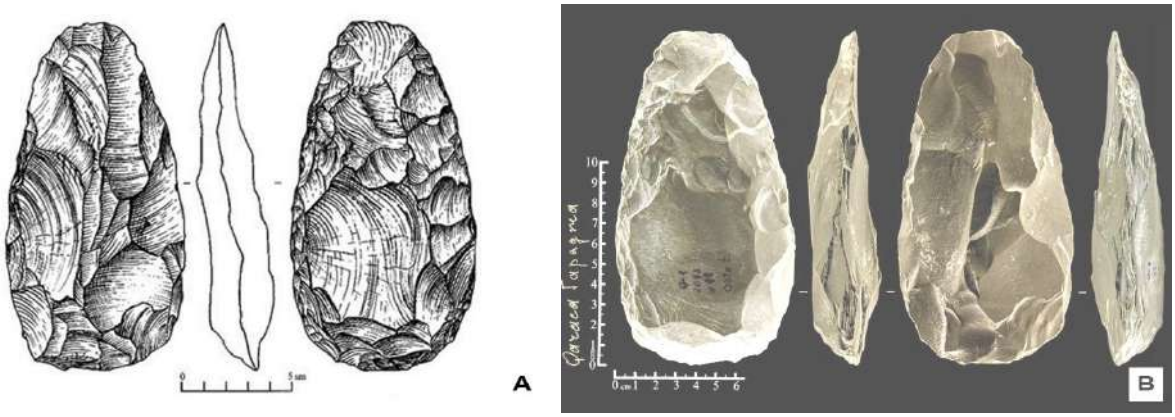

Fig. 18. Hand axes from the site Garaja: **A** graphic drawing; **B** photo image

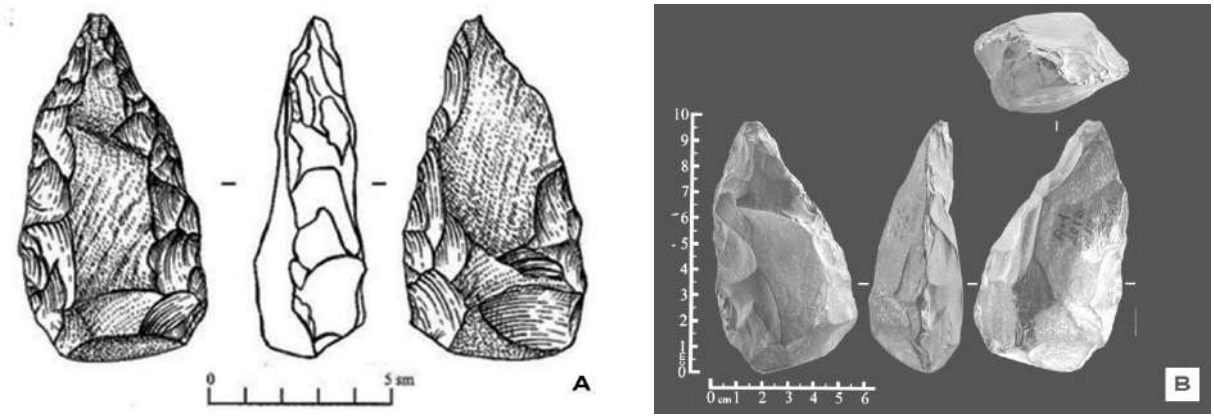

Fig. 19. Hand axes from the site Garaja: **A** graphic drawing; **B** photo image

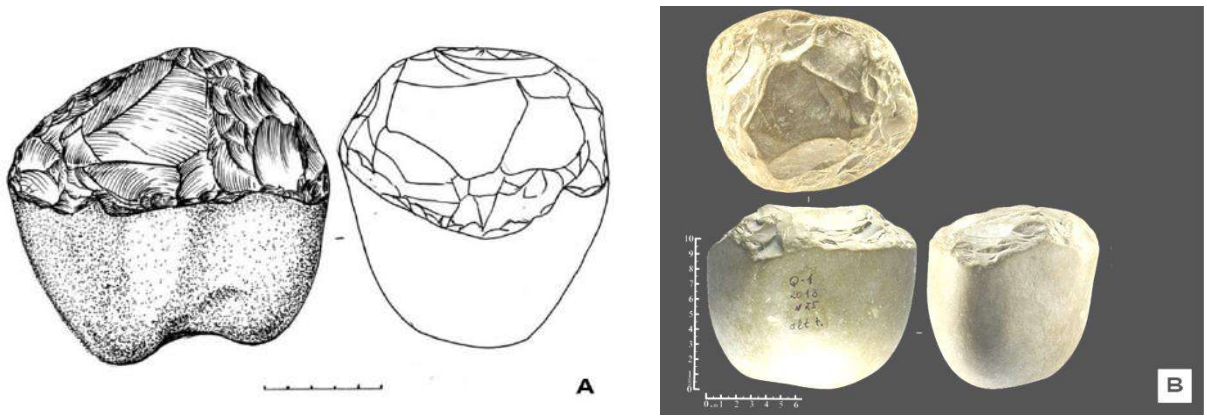

Fig. 20. Truncated pebbles from the site Garaja: **A** graphic drawing; **B** photo image

Among the choppers of Garaja industry, there are very large double-sides choppers made of very big pebble and weighing more than 3 kg. For the first time such kind of tool had been discovered in the lower layers of the case Azykh in Garabagh. They provided a basis for separating a new archeological culture – Guruchay. The large two-handed choppers up to 4,0-4,5 kg just were one of the criterion to separate a new culture. Huseynov M.M. had called those two-handed choppers as "gigantolithes". He was first who introduced into scholarly discourse the phrase "Guruchay culture" and the term "two-handed chopper-gigantolith" (Huseynov, 1979). Decades later, the mentioned culture founding form of "Guruchay cutlture" had been found not only in Garaja (Zeynalov, 2018), 300 km north of the cave Azykh but within the Lower Paleolithic man sites in the Central Dagestan (Amirkhanov, 2013), Taman peninsula (Kulakov, 2018), far beyond Azykh (Zeynalov and Zeynalova, 2018).

Currently, approximately 10 artefacts of such kind have been found on the shore of Mingachevir water reservoir. Some of these tools had been discovered at Garaja site directly. One of the tools had been made of large pebble 18,5x12,0x12,0-cm in size. The working edge, overlapping the lateral face, had been decorated by the large chips on the upper part of the tool (Fig. 21).

Some more tools had been found 5-6 km west of Garaja, at "Bozdag-1" archaeological site of findings. The chopper-gigantolith had been made by the same method as the previous one and of the same weight – over 3 kg. The tool is 18,0x18,0x8,0 cm in size. The chopper is double-sided. The working edge is decorated with large chips, resulting in a zigzag cutting edge. The natural crust had preserved over the rest surface of the tool.

One more two-handed chopper-gigantolith somewhat differs from two previous both in decoration technique and by weight. The double-sided chopper had been made using the large pebble (24,5x1,09x8,0 cm in size) of the subtriangular shape of dark grey colour. The tool weight is over 4 kg and very rounded. The working edge is decorated by large chips all-round taking 2/3 of the pebble. The natural crust had preserved on end-face and both sides of the pebble not touched by decoration (Fig. 22).

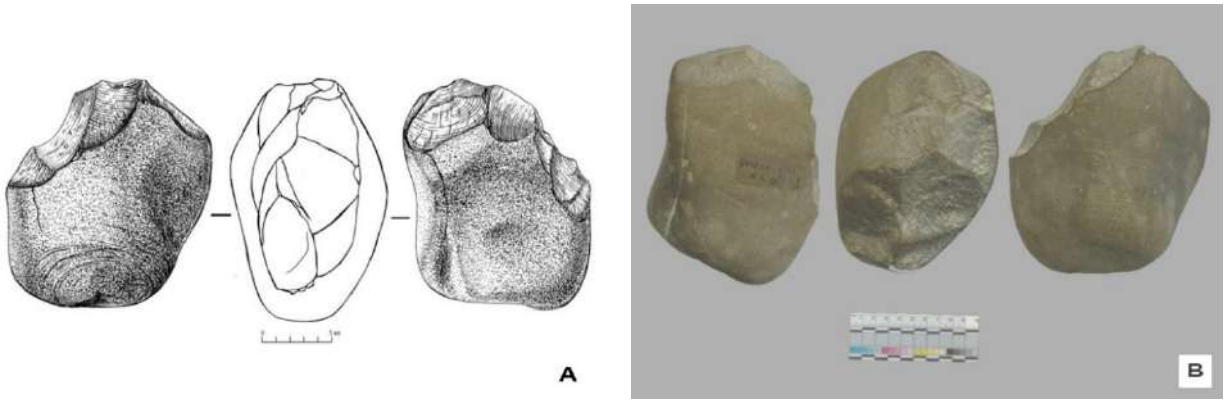

Fig. 21. Two-handed chopper-gigantolith from the site Garaja: **A** graphic drawing; **B** photo image

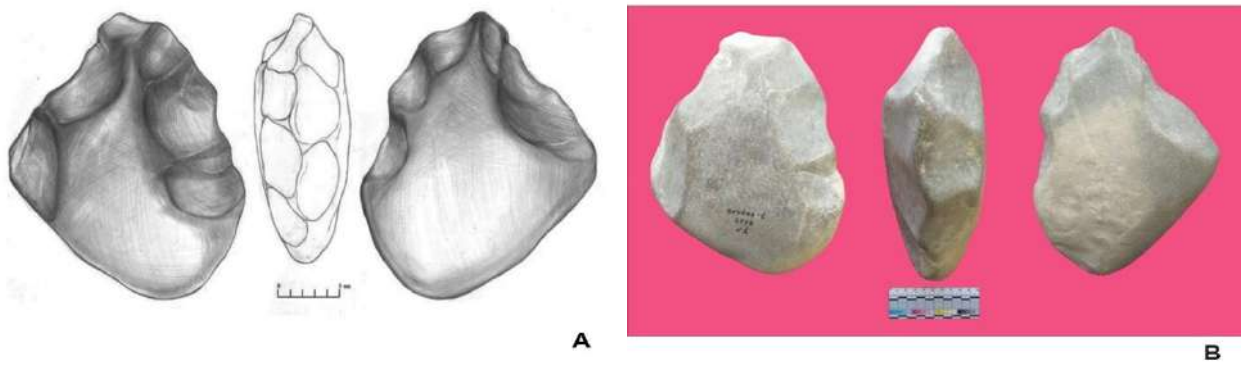

Fig. 22. Two-handed chopper-gigantolith from the site Bozdagh-1: **A** graphic drawing; **B** photo image

Some of the new-discovered choppers-gigantolithes do not meet all criteria of gigantolithes from the cave Azykh. In particular, there are differences in the raw materials and the working edge finishing. At the same time, all the artefacts had been made using the large pebbles. Their utilisation proposes the usage of both hands not only in the context of tool's weight but also its decoration when a vast surface keeps a smooth crusty face for easy handy gripe.

The discovery of new Lower Paleolithic sites in Azerbaijan, as well as in other regions of the Caucasus, says for the multi-vector routes of migration of the ancient populations of hominids to the Caucasus and Fore-Caucasus during the Lower Pleistocene. One of these routes was transition via the cave Azykh, Garaja on Kura River coast and further north to Dagestan group of the Lower Paleolithic sites.

Conclusion

Results of the multi-year research show that within the eastern part of the South Caucasus the paleogeographic environments of the Miocene-Pleistocene stage differed significantly from the modern ones. The found bone remains of the vertebrates as well as the abundance of remains of trunks of big and small trees and shrubs testify the domination of the semi-open landscapes of the forest-steppe type predominantly steppe areas, alternating with tree and shrubbery vegetation.

As a result of the carried out research it has been established that the area of Mingachevir water reservoir is the globally unique (over 100 km) cemetery of the vertebrate fossils. Besides it, this is the only place within the Caucasus where the remains of three species of the Pleistocene mammals of *Elephantidae* had been found.

The discovery of the Early Paleolithic sites in the Caucasus, including the recent ones in Azerbaijan, argues for the multi-vector migration routes of the ancient populations of hominids. The collected scientific content allows suggesting that after entering the Caucasus approximately 2 Ma the early hominids moved northward in two ways at the least archaeological material suggests that, having penetrated into the Caucasus about 2 million years ago, the oldest hominids migrated further northwards in two directions, at least. One way was directly towards Azykh and then due north via Garaja and then towards Dagestan group of the Lower Paleolithic sites. Another one migration ran to Dmanisi and also further north. It must be kept in mind that in Lower Pleistocene the Greater Caucasus range was forming and the steppe, forest-steppe and savanna landscapes prevailed in region.

The exclusive material based on the latest research outcomes had been firstly reported at the Conference "Ponto-Caspian Stratigraphy and Geochronology" (Tehran, Iran) and aroused great interest among the event participants. Considering the uniqueness of findspots of the Upper Miocene-Pleistocene vertebrate fauna in area of Mingachevir water reservoir and their eligibility for UNESCO and ProGeo, it is advisable to address the matter of granting region the status of the global geopark.

Declarations

The authors declare that they have neither financial nor non-financial interests. The authors declare that they have no conflict of interest. No Human Participants and / or Animals had been involved into the research.

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МИНГЯЧЕВИРСКИЕ МЕСТОНАХОЖДЕНИЯ ПЛЕЙСТОЦЕНОВОЙ ПОЗВОНОЧНОЙ ФАУНЫ И ПАЛЕОЛИТИЧЕСКИХ СТОЯНОК ГОМИНИДОВ КАК ГЕОСАЙТ МИРОВОГО ПРИРОДНО-ИСТОРИЧЕСКОГО НАСЛЕДИЯ (СЕВЕРО-ЗАПАДНЫЙ АЗЕРБАЙДЖАН)

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Резюме. Статья посвящена результатам исследования ископаемых позвоночных и раннепалеолитических местонахождений, расположенных на западе Азербайджана. В Джейранчельской степи и в окрестностях Мингячевирского водохранилища обнаружены богатейшие захоронения позвоночных в сочетании с раннепалеолитическими местонахождениями абшерон-бакинского времени. Такие местонахождения ископаемой позвоночной фауны как Эльдарское, Гушгунинское, Бождаг-Гараджинское, по праву оценены как уникальные геологические памятники (геосайты). Описывается история открытия и исследования описываемых геосайтов и раннепалеолитических местонахождений. Детальный анализ ископаемой фауны позволил выявить эксклюзивные для Кавказа виды плейстоценовых млекопитающих. Приводятся данные по палеогеографическим условиям миоцен-плейстоценого периода в восточной части Южного Кавказа, а также данные о геолого-геоморфологической ситуации в районе раннепалеолитического памятника Гараджа. На основе анализа геологической ситуации и остатков палеофауны определяются возможные временные рамки формирования памятника (бакинское время, 0,8-0,4 млн. л.н.). Проводится анализ археологических материалов. Комплексные исследования местонахождений ископаемой фауны и раннепалеолитических памятников позволили реконструировать палеогеографические условия обитания ископаемой фауны и ранних гоминидов в миоцен-плейстоценовый период. В результате проведенных исследований установлено, что окрестности Мингячевирского водохранилища являются уникальным по протяженности (более 100 км) кладбищем древних позвоночных ископаемых и сосредоточением раннепалеолитических памятников.

Ключевые слова: *Мингячевирское водохранилище, геосайт, позвоночная фауна, Азых, Гараджа, культура Гуручай*

DÜNYA TƏBİƏT-TARİXİ İRS GEOSAYTI – PLEYSTOSEN ONURĞALILAR FAUNASININ VƏ HOMİNİDLƏRİN PALEOLİT DÜŞƏRGƏLƏRİNİN MİNGƏÇEVİR MƏNTƏQƏLƏRİ (ŞİMAL-QƏRBİ AZƏRBAYCAN)

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Xülasə. Məqalə Azərbaycan Respublikasının qərbində yerləşən onurğalı heyvan qalıqlarının və Erkən Paleolit düşərgələrinin tədqiqat nəticələrinə həsr olunmuşdur. Ceyrançöl düzündə və Mingəçevir su anbarının ətrafında Abşeron-Bakı dövrünə aid Erkən Paleolit düşərgələri ilə yanaşı olaraq çox zəngin onurğalı qalıqları aşkar edilmişdir. Eldar, Quşquna və Bozdağ-Qaraca kimi onurğalı fauna qalıqlarının tapıldığı məntəqələr haqlı olaraq nadir geoloji abidələr (geosaytlar) kimi qiymətləndirilir. Məqalədə yuxarıda təsvir edilən geosaytların və erkən paleolit düşərgələrinin kəşfi və tədqiqat tarixi işıqlandırılır. Qazıntı faunasının ətraflı təhlili Qafqaz üçün eksklüziv olan Pleystosen məməlilər növlərinin müəyyən edilməsinə imkan vermişdir. Məqalədə Cənubi Qafqazın şərq hissəsində Miosen-Pleystosen dövrünün paleocoğrafi şəraiti, eləcə də Erkən Paleolit yaşlı Qaraca abidəsinin yerləşdiyi ərazinin geoloji-geomorfoloji mühiti haqqında məlumat verilir. Geoloji vəziyyətin və paleofauna qalıqlarının təhlili əsasında abidənin formalaşması üçün mümkün zaman çərçivəsi müəyyən edilir (Bakı dövrü, 0,8-0,4 milyon il əvvəl). Əlavə olaraq, arxeoloji materialların təhlili aparılmışdır. Qədim fauna qalıqlarının yerləşdiyi məntəqələrin və Erkən Paleolit abidələrinin kompleks tədqiqatı Miosen–Pleystosen dövründə fosil faunasının və erkən hominidlərin məskunlaşma şəraitini rekonstruksiya etməyə imkan vermişdir. Aparılmış tədqiqatlar nəticəsində müəyyən edilmişdir ki, Mingəçevir su anbarının ətrafı 100 km-dən artıq məsafəyə uzanan qədim onurğalı qalıqlarının unikal qəbiristanlığı və Erkən Paleolit dövrü abidələrinin cəmləşdiyi bir məkandır.

Açar sözlər: *Mingəçevir su anbarı, geosayt, onurğa faunası, Azıx, Qaraca, Quruçay mədəniyyəti*

Stratigraphy, petroleum sedimentology, geochemistry **2 / 2025**

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STUDY OF THE EFFECT OF HYDROCARBONS ON MAGNETIC CHANGES IN SOILS (AZERBAIJAN)

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Summary. The paper examines the observed changes in magnetic minerals exposed to hydrocarbons. The purpose of the magnetometric study was to identify the relationship between magnetic parameters and manifestations of oil-bearing formations. The oldest oil field, which is located on Pirallahi Island, was chosen as a control object for the study. We studied the magnetic parameters of samples from both sites to compare the magnetic parameters of soils from the Pirallahi oil field with soils not affected by the influence of hydrocarbon fluids from the Dubendi site. As a result of studying the magnetic parameters, it was found that some magnetic parameters of the Pirallahi oil field are hundreds (or more) times higher than those of the Dubendi area. Both magnetic and chemical studies of the studied soil samples have shown the presence of magnetic minerals: magnetite and hematite. The carrier of magnetization is magnetite on the Pirallahi oil field. The magnetic mineral is hematite for the Dubendi region. Thus, as a result of the petromagnetic studies and chemical analyses, the reason for the observed increase in the magnetic signal over the Pirallahi oil field was identified. In the studied soils of the Pirallahi oil field, the magnetite grains found belong to the fine-grained magnetic fraction. In the Dubendi area, which is not affected by hydrocarbon impact, finely dispersed hematite was found as a magnetization carrier.

Keywords: *petro magnetism, soil magnetism, hydrocarbons, Pirallahi Oil Field*

Introduction

In recent decades, numerous scientific papers have been published indicating that oil and gas reservoirs can be detected using micro-magnetic methods. The micro-magnetic method consists of a combination of high-resolution magnetic surveys (Gadirov, 2013) with detailed rock-magnetic examination of sediments and soils to detect changes in magnetic and iron-bearing minerals caused by hydrocarbon seepage (Badejo, 2021; Benthien and Elmore, 1987; Foote, 1992; Ellwood and Burkart, 1996; Liu et al., 1998a; Liu et al., 1998b; Liu and Liu, 1999; Goldhaber and Reynolds, 1991). Magnetic studies (Elmore et al., 1987; Elmore and Crawford, 1990) indicate a genetic relation between hydrocarbon migration and the precipitation of authigenic magnetite.

Magnetic minerals are formed or changed in the presence of hydrocarbons. Near-surface samples of soils and sandstones from oil and gas fields (Díaz et al., 2000; Abdulkarim et al., 2022; Aldana et al., 2003; Costanzo-Alvarez et al., 2006; Emmerton et al., 2013) revealed the presence of authigenic magnetite in them. On the other hand, when studying near-surface samples of soils and sandstones where there are no oil and gas deposits (i.e., accumulations of hydrocarbons), the presence of any magnetite has not been revealed. Magnetic exploration work carried out in areas of oil and gas fields recorded abnormal magnetic field signals (Donovan et al., 1979; Gadirov, 2013).

Hydrocarbons do not have significant magnetic properties capable of causing a geomagnetic field anomaly over oil and gas reservoirs. The cause of Such anomalies is the appearance of newly formed magnetic and iron-containing minerals in soils and sandstones under conditions of hydrocarbon seepage (Benthien and Elmore, 1987; Saunders et al., 1991; Foote, 1992; Ellwood and Burkart, 1996; Goldhaber and Reynolds, 1991; Liu and Liu, 1999; Liu et al., 1998a; Guliyev et al., 2003). Magnetic methods can be used for additional oil and gas exploration and prospecting.

As noted, hydrocarbon reservoirs are often associated with prominent magnetic anomalies, presumably caused by diagenetic alteration of magnetic and other iron-bearing minerals in hydrocarbon (oil) seepage environments. However, the mechanisms and pathways of hydrocarbon-induced magnetic changes remain poorly understood, making it difficult to develop reliable magnetic-based exploration and environmental monitoring methods. As it is known, hydrocarbons do not have magnetic properties capable of causing a magnetic anomaly over an oil and gas reservoir. The question is: where does the source of the anomaly come from? The reason is the interaction of seeping hydrocarbon fluids with rocks encountered on the migration route.

Today, we know three mechanisms that explain the formation of the secondary magnetic minerals that develop in a hydrocarbon environment due to the seepage of hydrocarbon fluids. The first model describes diagenetic changes in magnetite. This model was first proposed by Donovan et al. (1979) based on aeromagnetic surveys at the Cement oil field in the Anadarko Basin, Oklahoma. They suggested that diagenetic magnetite forms as a result of seeping hydrocarbons. Diagenetic magnetite occurs through the substitution of Fe^{3+} from hematite for Fe^{2+}. In the second model, a more significant role is likely played by changes in pyrite. According to Pirson (Pirson, 1982), the location of oil and gas reservoirs is determined using the induced polarization (IP) method, which is based on pyrite changes. Research by Reynolds et al. (1990a, 1990b) and Goldhaber and Reynolds (1991) examines the relationship between microseepage of hydrocarbons and iron sulfide minerals. They believe that pyrrhotite causes the magnetic anomalies. They argue that pyrite (FeS_2), which forms in large quantities due to hydrocarbon seepage, adheres to pyrrhotite creating an abnormal magnetic signal. A third model, which explains the formation of an abnormal magnetic signal focuses on siderite (iron carbonate). In a hydrocarbon environment, siderite formation is widespread. This process increases rock magnetization, which can be useful in paleomagnetic studies (Reynolds et al., 1990a; Elmore and Crawford, 1990).

Due to its variable valence, iron, which is part of finely dispersed oxides and hydroxides, can participate in various chemical reactions. In particular, iron, which is part of finely dispersed oxides and hydroxides, can be reduced. Sedimentary rocks containing iron oxides and hydroxides can reduce iron oxides and hydroxides when exposed to fluids of migrating hydrocarbons. These reducing geochemical reactions lead to new iron-containing compounds with magnetic properties.

Scientific studies have shown that hydrocarbon deposits are often associated with noticeable magnetic anomalies, which may be caused by diagenetic changes in magnetic and other iron-containing minerals under conditions of hydrocarbon seepage. However, the mechanisms and pathways of magnetic changes caused by hydrocarbons remain poorly understood, which prevents the development of reliable monitoring methods based on magnetic measurements.

Thus, it is possible to determine the migration routes and accumulation zones of hydrocarbons using petromagnetic and magnetic-mineralogical data of the studied soils and sandstones. Petromagnetic studies are a potential magnetic proxy for determining hydrocarbon migration routes. In addition, this useful data on the magnetic properties of hydrocarbon-exposed soil and sandstone samples will allow determining the (surface) contours of oil and gas reservoirs in the Earth's crust.

Comprehensive studies (Abdulkarim et al., 2022; Aldana et al., 2003; Benthien and Elmore, 1987; Donovan et al., 1979; Elmore et al., 1987; Elmore and Crawford, 1990; Gadirov, 2013; Gadirov et al., 2023; Goldhaber and Reynolds, 1991; Perez-Perez et al., 2011; Saunders et al., 1991; Yuan et al., 2018, etc.) of magnetic fields conducted over oil and gas reservoirs, as well as rock magnetic studies (Emmerton et al., 2013; Liu et al., 1998a; Liu and Liu, 1999; Liu et al., 1998b; Menshov et al., 2015; Menshov et al., 2016; Novruzov et al., 2023a; Новрузов и др., 2023b; Novruzov et al., 2022a; Novruzov və b., 2022b; Orlyuk et al., 2018, etc.) of soil (rock) sampled directly from the areas of oil and gas fields, make it possible to improve understanding of the nature of the anomalous behavior of the geomagnetic field over hydrocarbon deposits. Further researches related to the study of the influence of hydrocarbons on the magnetic properties of soils (host rocks) and how this influence changes the magnetic and mineralogical composition of the properties of soils (host rocks) will make a significant contribution to understanding the essence of the process.

Rock Magnetic Measurements

Field measurements and sampling

As a control object of the study, the territory of the Pirallahi oil field was chosen. The Pirallahi Island is located on the eastern side of the Absheron Peninsula at a distance of about 50 km from the city of Baku (Fig. 1). The Pirallahi oil field has been in operation for over a hundred years. Crude oil is still being extracted from this oldest field today.

We studied the magnetic properties of oil-saturated soils and sandstones from the Pirallahi oil field. The study was aimed at identifying the changes in magnetic minerals in oil-saturated soils and sandstones exposed to hydrocarbon fluids.

At the Pirallahi oil field, samples were taken from depths of 0-0.5 m (from the earth's surface) from 10 points for magnetic studies (Fig. 2 and Fig. 3). At each sampling point, magnetic susceptibility was measured *in situ*. At the hydrocarbon-free Dubendi site (Fig. 2), magnetic susceptibility was also measured *in situ*.

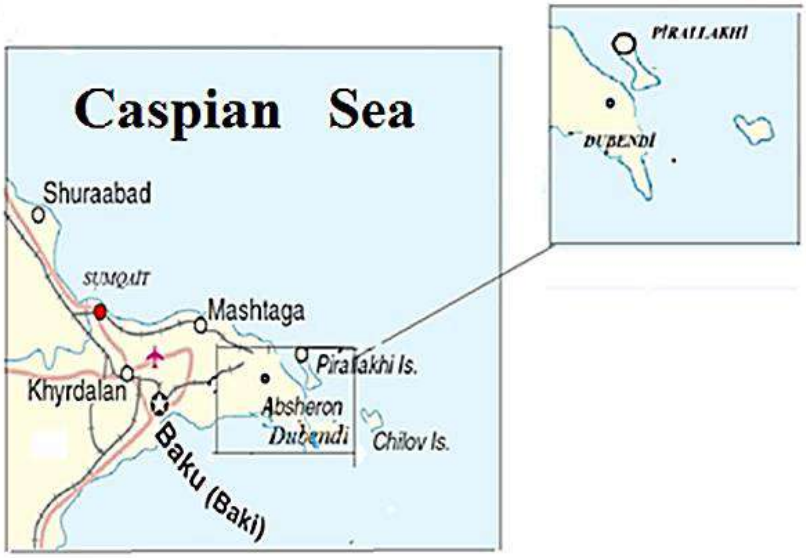

Fig. 1. Location of the study areas on Pirallahi Island and in the ecologically clean the Dubendi region

Fig. 2. Sampling locations at the Pirallahi oil field (samples 1-10) and at the ecologically clean Dubendi area (samples 11-13)

Samples were also taken from the Dubendi area for magnetic studies in the laboratory of the institute. By a pre-developed scheme, rock samples (with CPS determination) were taken near the operating oil wells. The sampled soil specimens were placed in special non-magnetic plastic containers. Each plastic container was labeled and corresponded to one sampling location.

Laboratory magnetic research

The sampled soil specimens were then taken for laboratory magnetic measurements. Such magnetic parameters as the natural remnant magnetization NRM (I_n) and the volumetric magnetic susceptibility (k) were measured in laboratory conditions. Further, various types of induced magnetizations were created. The induced magnetizations of various types were then demagnetized using alternating magnetic field techniques and a gradual temperature increase. Due to the laboratory experimental procedures, the values of isothermal remnant magnetization IRM and saturation isothermal remnant magnetization SIRM, total temperature remnant magnetization TRM, and alternative remnant magnetization ARM were obtained and measured. In the course of laboratory work, temperature demagnetization curves and curves of demagnetization by an alternating magnetic field were constructed. In addition, the ratios of the values of various types of induced magnetizations were calculated.

Thermomagnetic curves show the magnetic phase of a mineral and provide data on the changes that occur during heating. For example, chemical remagnetization can promote the formation of goethite or the transformation of hematite into magnetite. IRM measurements allow the separation of ferrimagnetic phases. The IRM method provides reliable data on the separation of ferromagnetic phases. Minerals with the same coercivity often have different unblocking temperatures. According to the Lowrie test (Lowrie, 1990), three different components of saturation magnetization are acquired by the sample: in the Z direction – 1 T, then in the Y direction by applying a field of 0.4 T, and in the X direction – 0.12 T. Thermal cleaning of the sample will isolate these components and interpret them in terms of the temperature range at which each component loses its magnetization.

As iron ions of certain groups of minerals can migrate from one crystal lattice to another, these minerals are susceptible to diagenetic oxidation (Ozdemir et al., 1993; Liu and Liu, 1999). The minerals containing iron oxides include magnetite, maghemite, and hematite. The group of oxyhydroxides includes goethite, ferrihydrite, and lepidocrotite. The group of sulfites includes greigite and pyrrhotite.

Magnetic Analysis

Magnetic studies were conducted at the Institute of Geology and Geophysics of the Ministry of Science and Education of the Republic of Azerbaijan. Several types of measurements were carried out: 1) measurement of the volume (bulk) magnetic susceptibility k; 2) measurement of the dependence of the isothermal remnant magnetization on the effect of the applied direct magnetic field (in fields from 2 to 700 A/m in 20 steps; 3) measurement of the temperature dependence of the isothermal remnant magnetization from 20°C to 800°C (measurements were carried out in the range from 20°C to 800°C under atmospheric conditions); 4) measurement of the following parameters of magnetic hysteresis: isothermal saturation remnant magnetization (Mrs), coercive force (Hc) and coercive force of remnant magnetization (Hcr). We have obtained data that will be used to create distribution maps of magnetic susceptibility and other magnetic parameters to assess the dependence of magnetic changes on the distance of the hydrocarbon reservoir.

The remnant magnetization was measured using a high-precision JR-6 instrument (Agico, Czech Republic). The measurement range of this device exceeds 11 levels (10^{-6}–10^{4} A/m). For the creation of thermo-remnant magnetization (TRM), the MMTD 24 thermal furnace (UK) was used-fully automated with high-precision temperature control. For the creation of isothermal saturation remnant magnetization (SIRM), a PAM1 magnetizer (Agico, Czech Republic) was used. A LDA5 device (Agico, Czech Republic) was used to create alternative remnant magnetization (ARM).

A rotary two-component thermo-magnetometer designed by Burakov-Vinogradov (Institute of Earth Physics, Russia) was used for magnetic and mineralogical analyses of the studied rocks. Thermomagnetic demagnetization of the studied sample was carried out using this device. Based on the course and shape of the thermo-

magnetic demagnetization curves, both the component composition of magnetic minerals in the sample and the possible newly formed magnetic mineral during heating were determined.

Results and discussion

Demagnetization curves in an alternating magnetic field of induced magnetizations of SRM, TRM, and ARM were plotted and analyzed. The induced acquired SRM, TRM, and ARM curves were also analyzed. In addition, the NRM/ARM and TRM/TRM ratios were calculated.

The obtained data on the magnetic data of the studied samples identifies the most sensitive magnetic parameters (or their ratios) that reflect the oil saturation of the rocks. Using these parameters, we estimate the area where oil-saturated rocks are distributed and thereby outline the contours of the oil and gas reservoirs located in the Earth's crust.

In point 1, soil specimens were sampled from the surface. At a depth of 30 cm at the same point, sandstone was sampled. The volume magnetic susceptibility of a soil sample taken from the surface is $k = 0.74 \times 10^{-3}$ SI units, at a depth of 10 cm, $k = 0.26 \times 10^{-3}$ SI units, and at a depth of 30 cm, $k = 0.31 \times 10^{-3}$ SI units. The second sampling point is approximately 50-60 m north of the first sampling point. Magnetic susceptibility of the soil at the second sampling point: from the surface is equal to $k = 0.17 \times 10^{-3}$ SI units, from a depth of 15 cm $k = 0.09 \times 10^{-3}$ SI units, and from a depth of 40 cm $k = 0.10 \times 10^{-3}$ SI units. At the third sampling point, on the surface, the soil samples have a volume susceptibility $k = 12 \times 10^{-3}$ SI units, at a depth of 10 cm, $k = 4.68 \times 10^{-3}$ SI units. It can be said that around this sampling point of approximately 50×100 m^2, the volumetric magnetic susceptibility values are quite high. The fourth soil specimen was sampled in the area of well No. 249. At the surface, the volume magnetic susceptibility was $k = 0.60 \times 10^{-3}$ SI units.

The fifth soil specimen point was selected in the northwestern part of the Pirallahi oil field. On the surface, $k = 2.15 \times 10^{-3}$ SI units, at a depth of 10 cm, $k = 3.4 \times 10^{-3}$ SI units, at a depth of 30 cm, $k = 6.33 \times 10^{-3}$ SI units. In the northern direction of the soil and sandstone sampled specimens, the volume magnetic susceptibility. The volumetric magnetic susceptibility of the samples gradually decreased as they moved towards borehole No. 1039 at 30-40 m from sampling point 5.

Fig. 3. Schematic location of soil sampling points in the study area: sampling points are indicated by black circles

The volume magnetic susceptibility of the soil measured on the surface at sampling point 6 was $k = 1.88 \times 10^{-3}$ SI units, and at a depth of 15 cm, $k = 0.24 \times 10^{-3}$ SI units.

At sampling point 7, the volume magnetic susceptibility of the soil measured on the surface was $k = 0.26 \times 10$-3 SI units at a depth of 15 cm $k = 0.48 \times 10$-3 SI units, and a depth of 30 cm $k = 0.08 \times 10^{-3}$ SI units.

Volume magnetic susceptibility of the soil measured on the surface at sampling point 8 on the surface $k = 0.36 \cdot 10^{-3}$ SI units, at a depth of 15 cm $k = 0.06 \times 10^{-3}$ SI units.

Sampling point 9 had a volumetric magnetic susceptibility on the surface $k = 1.90 \times 10^{-3}$ SI units, at a depth of 15 cm $k = 2.75 \times 10^{-3}$ SI units. At a depth of 20 cm, the volumetric magnetic susceptibility $k = 0.58 \times 10^{-3}$ SI units.

At sampling point 10, the volume magnetic susceptibility $k = 4.26 \times 10^{-3}$ SI units on the Earth's surface.

A local map of changes in volumetric susceptibility of soils is shown in Fig. 4.

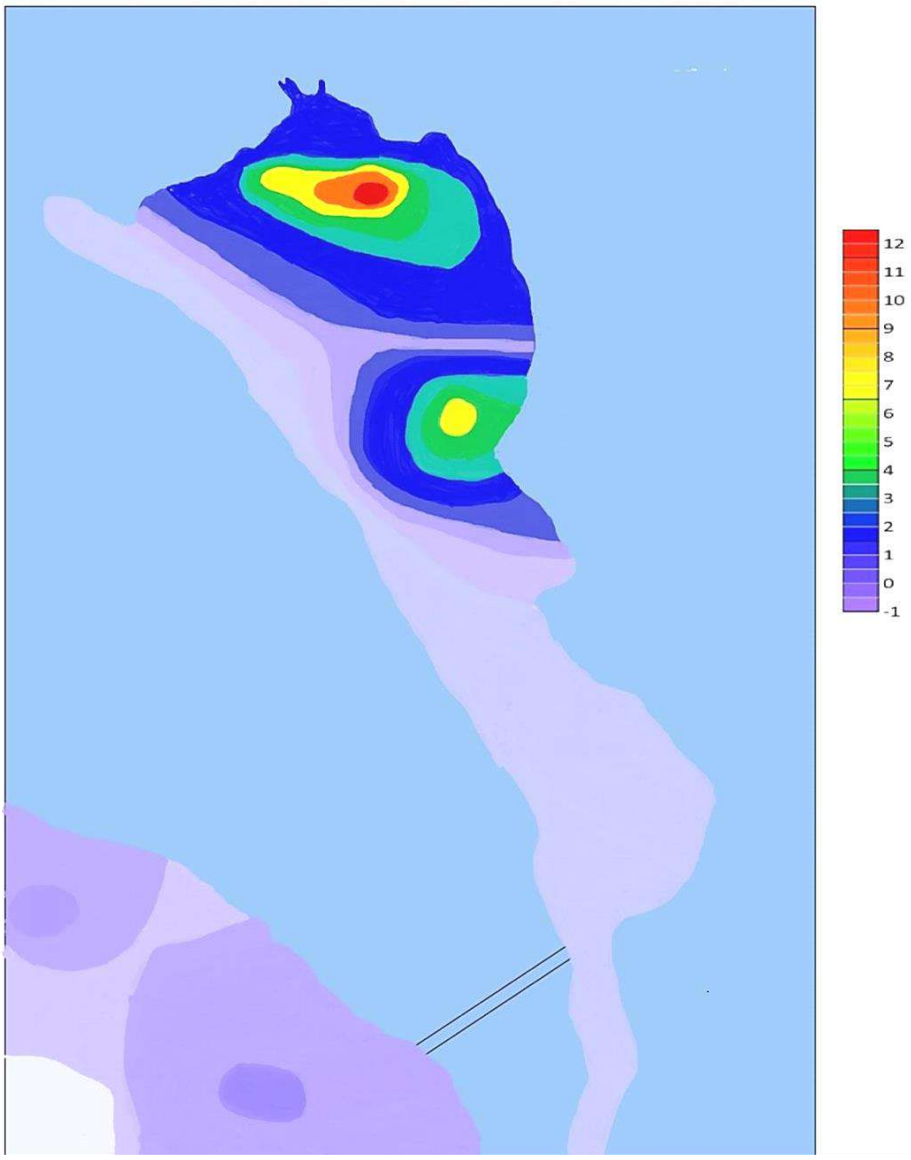

Fig. 4. Change in magnetic susceptibility of soils in the study area of the Pirallahi and Dubendi (color scale is indicated in units of 1×10^{-3}SI units)

Large accumulations of the secondary magnetite formations can explain the anomalous values of *k* at sampling points 3 and 5. At point 5, the observed increase with depth in the volume magnetic susceptibility (at the surface $k = 2.15\times10^{-3}$ SI units, at a depth of 10 cm $k = 3.4\times10^{-3}$ SI units, and at a depth of 30 cm $k = 6.33\times10^{-3}$ SI units) can be explained by the proximity of the paths (microcracks) along which the leaking (percolating through) hydrocarbon fluids affected the formation of new secondary magnetite minerals. This assumption is confirmed by chemical analysis of soil and sandstone samples conducted at the Analytical Center of the Institute of Geology and Geophysics. In addition, the conducted thermomagnetic analysis (Fig. 5) of the samples indicates the secondary magnetite formations at the oil field under study.

To compare the effect of hydrocarbon seepage on the formation and change of magnetic minerals in the studied area of the Pirallahi oil field, we sampled soil specimens from both Pirallahi Island and the ecologically clean Dubendi area near the island. The volume magnetic susceptibility of samples from the Dubendi area was also measured in the field. They were packed in plastic non-magnetic containers for petromagnetic researches in the Institute of Geology and Geophysics of the Ministry of National Economy of the Council of Ministers, Baku, Azerbaijan.

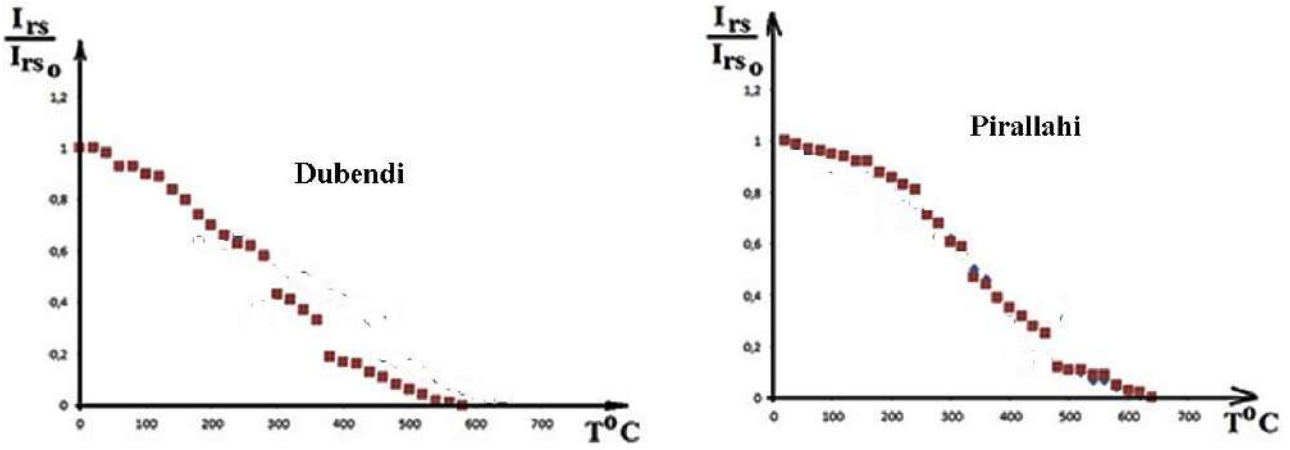

Fig. 5. Thermomagnetic demagnetization curves of soil samples from the Pirallahi and Dubendi regions

The I_{rs} (T) curves determined the Curie point of the studied rocks. The saturation isothermal remnant magnetization (SIRM) curves of temperature dependence were analyzed for all sampled soil specimens. At the Pirallahi oil field, based on the results of thermomagnetic analysis, it was established that magnetite is the carrier of magnetization. At the Dubendi site, which is unaffected by hydrocarbon influence, hematite is the carrier of magnetization (Fig. 5). Typical temperature demagnetization curves are shown in Fig. 5. As we can see in Fig. 5 for the Dubendi area, the temperature demagnetization curve of the samples has an almost linear demagnetization curve up to the Curie point equal to 625°C. Such a curve with Tc = 625ºC may indicate a spectrum of finely dispersed hematite-blocking temperatures (Авилова и др., 1978). This assumption is confirmed by the fact that the Curie point of fine-grained hematite (To=625°C) is significantly smaller than the Curie point of coarse-grained hematite (Tc=675°C) (Новрузов и др., 2023b).

The isothermal remnant magnetization (IRM) was acquired in increments of 20 mT. The IRM acquisition curve is shown in Fig. 6. Progressively increasing magnetic fields applied to samples revealed two types of magnetic minerals. One of them becomes saturated at an applied field of 200 mT. A magnetic mineral that reaches saturation in a 200 mT field indicates the presence of magnetite. In the other case, the magnetic mineral saturates in a 1000 mT field, indicating the presence of hematite in the studied sample. The Curie point of 625-635°C corresponds to fine-grained hematite (Fig. 6). The isothermal remanent magnetizations, reaching saturation fields of 200 mT and 1000 mT, correspond to magnetite and fine-grained hematite, as shown in Fig. 6. Thus, the results of the progressive magnetization of samples to saturation magnetization confirmed the results of the thermomagnetic analysis.

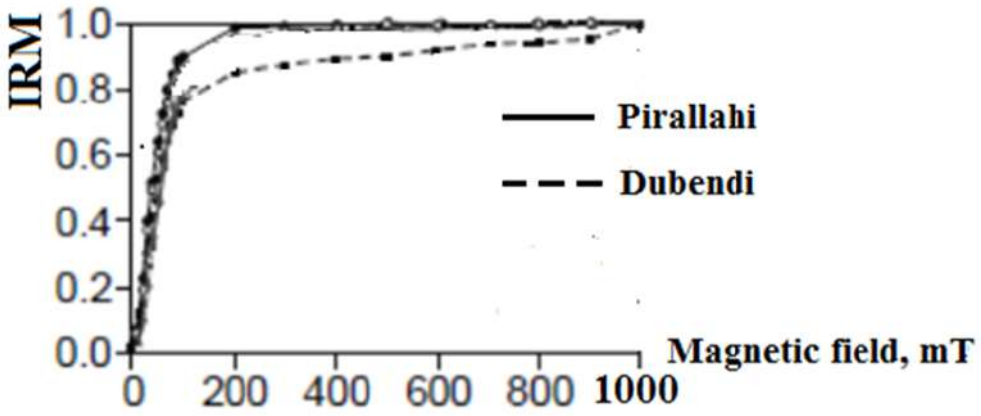

Fig. 6. Curves of stepwise isothermal magnetization of samples up to saturation from the Pirallahi and Dubendi regions

Conclusions

Magnetic studies conducted at the Pirallahi field revealed the influence of hydrocarbons on the change and appearance of new magnetic minerals in the soil and sandstones of the studied territory of the Pirallahi oil field. As a result of the interaction of oil-hydrocarbon fluids with the soils and sandstones, new secondary magnetite minerals were formed, which caused an anomalous signal in the area impregnated with hydrocarbons.

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ИЗУЧЕНИЕ ВЛИЯНИЯ УГЛЕВОДОРОДОВ НА МАГНИТНЫЕ ИЗМЕНЕНИЯ В ПОЧВАХ (АЗЕРБАЙДЖАН)

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Резюме. В статье рассматриваются наблюдаемые изменения в магнитных минералах, подвергшихся воздействию углеводородов. Целью магнитометрического исследования было выявление взаимосвязи между магнитными параметрами и проявлениями нефтеносных пластов. В качестве контрольного объекта для исследования было выбрано старейшее нефтяное месторождение, расположенное на острове Пираллахи. Чтобы сравнить магнитные параметры почв с нефтяного месторождения Пираллахи с почвами, не подверженными воздействию углеводородных флюидов с участка Дюбенди, мы изучили магнитные параметры образцов с обоих участков. В результате изучения магнитных параметров было установлено, что некоторые магнитные параметры нефтяного месторождения Пираллахи в сотни (или более) раз превышают таковые в районе Дюбенди. Как магнитные, так и химические исследования изученных образцов почвы показали наличие магнитных минералов: магнетита и гематита. Для нефтяного месторождения Пираллахи носителем намагниченности является магнетит. Для региона Дюбенди магнитным минералом является гематит. Таким образом, в результате петромагнитных исследований и химических анализов была выявлена причина наблюдаемого увеличения магнитного сигнала над нефтяным месторождением Пираллахи. В исследованных почвах нефтяного месторождения Пираллахи обнаруженные зерна магнетита относятся к мелкозернистой магнитной фракции. В районе Дюбенди, который не подвержен воздействию углеводородов, в качестве носителя намагниченности был обнаружен мелкодисперсный гематит.

Ключевые слова: *петромагнетизм, почвенный магнетизм, углеводороды, нефтяное месторождение Пираллахи*

KARBOHİDROGENLƏRİN TORPAQLARDA MAQNİT DƏYİŞİKLİKLƏRİNƏ TƏSİRİNİN ÖYRƏNİLMƏSİ (AZƏRBAYCAN)

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Xülasə. Məqalədə karbohidrogenlərə məruz qalan maqnit minerallarında müşahidə olunan dəyişikliklər araşdırılır. Maqnitometrik tədqiqatın məqsədi maqnit parametrləri ilə neft yataqlarının təzahürləri arasındakı əlaqəni müəyyənləşdirmək idi. Tədqiqat üçün nəzarət obyekti olaraq Pirallahı adasında yerləşən ən qədim neft yatağı seçildi. Pirallahı neft yatağından torpaqların maqnit parametrlərini Dübəndi sahəsindən karbohidrogen mayelərinə məruz qalmayan torpaqlarla müqayisə etmək üçün hər iki sahədən nümunələrin maqnit parametrlərini araşdırdıq. Maqnit parametrlərinin öyrənilməsi nəticəsində Pirallahı neft yatağının bəzi maqnit parametrlərinin Dübəndi bölgəsindən yüzlərlə (və ya daha çox) dəfə çox olduğu müəyyən edilmişdir. Tədqiq olunan torpaq nümunələrinin həm maqnit, həm də kimyəvi tədqiqatları maqnit minerallarının mövcudluğunu göstərdi: maqnetit və hematit. Pirallahı neft yatağı üçün maqnitləşmə daşıyıcısı maqnetitdir. Dübəndi bölgəsi üçün hematit maqnit mineraldır. Beləliklə, petromaqnit tədqiqatları və kimyəvi analizlər nəticəsində Pirallahı neft yatağı üzərində müşahidə olunan maqnit siqnalının artmasının səbəbi müəyyən edilmişdir. Pirallahı neft yatağının tədqiq edilmiş torpaqlarında aşkar edilmiş maqnetit dənələri incə dənəli maqnit fraksiyasına aiddir. Karbohidrogenlərə məruz qalmayan Dübəndi bölgəsində maqnitləşmə daşıyıcısı olaraq incə dağılmış hematit aşkar edilmişdir.

Açar sözlər: *petromaqnetizm, torpaq maqnetizmi, karbohidrogenlər, Pirallahı neft yatağı*

Stratigraphy, petroleum sedimentology, geochemistry **2 / 2025**

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EXPLORATION PERSPECTIVES OF THE KARABAKH FIELD IN THE SOUTH CASPIAN BASIN

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Summary. The Karabakh field, situated in the northern Absheron Archipelago within the South Caspian Basin, presents significant hydrocarbon potential, primarily in the Lower and Upper Kirmaki formations. Initially, the field was discovered in 1998 by the Caspian International Operating Company consortium. The project was suspended in 1999, when the oil price was 25–26 dollars per barrel. Despite the discovery of the fields, the project was closed due to the oil and gas reserves being deemed economically unfeasible for development. However, in 2018, its development began within the framework of a contract signed between SOCAR and Equinor.

Geological studies, including stratigraphy, well logging, and petrophysical interpretations, were conducted on data from three wells (KPS-1 to KPS-3) with notable production test success in KPS-2. Positive gas and condensate results were identified from both the Lower Kirmaki and Upper Kirmaki sandy intervals highlighting the commercial viability of the field.

The structural complexity of the region marked by asymmetric folds, thrust faults, and lithological variability–poses significant exploration and drilling challenges. Stratigraphic assessments reveal a thick sequence of sandy-argillaceous formations, with key reservoirs demonstrating high porosity (up to 22%) and sand content (up to 75%). Drilling operations have been impeded by unstable pore pressures, clay swelling, and overpressure zones, particularly in the Gala and Miocene Formations. The presence of montmorillonite-rich clays further complicates borehole stability.

Comparative regional analysis and historical data from the adjacent fields support the Karabakh potential but underscore the need for further appraisal. Recommendations include the targeted drilling, enhanced seismic analysis, updated petrophysical interpretation, and rigorous pressure management. Addressing these technical and geological uncertainties is essential to unlock the full economic potential of the Karabakh field and ensure safe, efficient offshore development.

Keywords: *The South Caspian Basin, oil and gas exploration, petrophysical log analysis, lithology, stratigraphy, drilling*

Introduction

The Karabakh field is located in the northern sector of the Absheron Archipelago, within the North Absheron uplift zone of the South Caspian Basin (Ronchitelli, 1999). Geographically, it lies approximately 120 km southeast of Baku and 85 km offshore from the Absheron Peninsula. It is situated 20-25 km northeast of the Neft Dashlari and Guneshli oil fields. The region features moderate sea depths ranging from 130 to 180 meters and is underlain by modern Caspian sediments, including clay sands, sandstones, and shell debris. Deeper geological intervals are predominantly composed of compact clays (Fig. 1).

Following the State Program for the Development of the Petroleum and Energy Complex of Azerbaijan, adopted in 2005, SOCAR began design work in 2006 for the development of the Karabakh field, which was originally discovered by the CIPCO Consortium in 1998. Proven hydrocarbon reserves in the field are estimated at 16 million tons of oil and 20 billion cubic meters (BCM) of gas.

SOCAR commissioned its Caspian Offshore Oil and Gas Project Institute to develop a comprehensive project plan, including the design of a drilling and production platform and associated subsea pipelines. The project includes the construction of a drilling and production platform equipped for 12 wells (8 gases and 4 oils). The development plan was submitted to SOCAR for review and approval in February 2007. Following the contractual phase – covering platform and pipeline construction, drilling equipment procurement, and other tangible assets – oil and gas production was projected to begin in late 2008 or

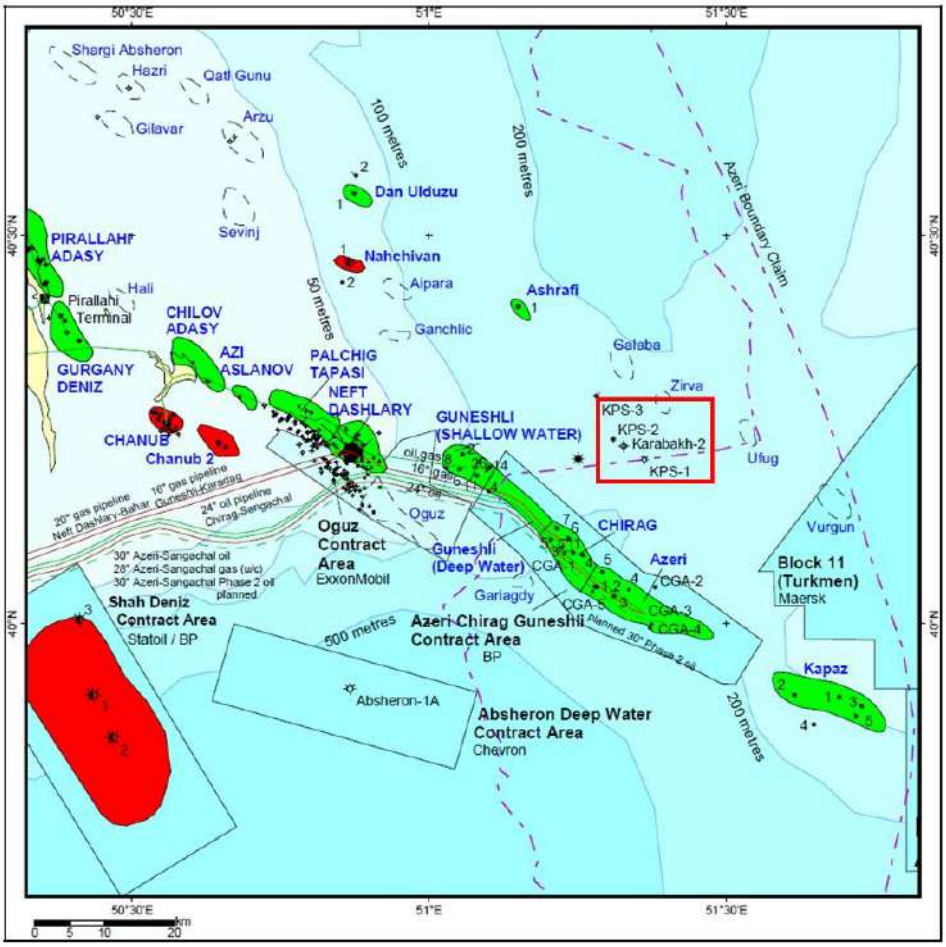

Fig. 1. Karabakh location map

early 2019. In its initial phase, the project was expected to significantly increase SOCAR's hydrocarbon production.

SOCAR opted not to employ advanced drilling and production technologies such as horizontal drilling or open-hole gravel packs at the Karabakh field. Preliminary estimates set the capital expenditure for full field development at approximately $200 million. Despite the potential of the project, few foreign oil companies have expressed willingness to co-finance and co-develop the field with SOCAR. The status of these negotiations remains unclear (Azerbaijan Petroleum Industry Review, 2007).

On May 31, 2018, SOCAR and Equinor signed a Risk Service Contract in Baku for the development of the Karabakh field. The agreement was ratified by the National Assembly of Azerbaijan on June 29, 2018, and entered into force on July 5. The project was to be carried out through a jointly operated company with a 50/50 ownership structure (Caspian Barrel, 2019). However, in 2024, Equinor divested all its remaining assets in Azerbaijan to SOCAR, making SOCAR the sole operator of the project.

Wells KPS-1, KPS-2, and KPS-3 were drilled using the "Dada Gorgud" rig. The elevation of all three wells was 22 meters, with water depths of 180 m for KPS-1, 176 m for KPS-2, and 181 m for KPS-3. The rig was positioned on August 5, 1997. Drilling operations commenced on KPS-1 on August 8, 1997, and concluded on November 21, 1997. KPS-2 was drilled from April 8 to July 1, 1998, and KPS-3 from September 21 to November 3, 1998. The KPS-4 well was also drilled using the same rig (Photo 1).

Materials and Methods

Between 1997 and 1998, biostratigraphic consultancy was provided to CIPCO Operation Company for a study based on cuttings and core samples obtained from three deep exploration wells in the Karabakh region (Table 1).

Photo 1. "Dada Gorgud" rig (https://www.caspiandrilling.com/browse.php?sec_id=12)

In 2007, during the course of the Ashrafi-Karabakh project conducted by the German company Wintershall, official well log data were acquired from SOCAR. These data were originally available only in paper format but were subsequently digitized and edited by Petrologic Data Services GmbH. The finalized dataset was delivered in LAS digital format with a sampling interval of 0.1524 meters. Rigorous quality control of the log data for the Karabakh-2 and Karabakh-3 wells was carried out by Mr. Richard Culpman, confirming their reliability. For other intervals, only low-resolution composite logs were accessible. As a result, the detailed analysis and achievement of the project objectives were primarily feasible for the Karabakh-2 and Karabakh-3 wells, whereas interpretations of the Karabakh-1 well were considered qualitative rather than quantitative.

Petrophysical interpretations of the Karabakh wells were performed in collaboration with Mr. Culpman. All formation tops in the logs were corrected manually. A standard deterministic interpretation was conducted using Interactive Petrophysics software under Mr. Culpman's supervision.

Prior to 1997, biostratigraphic analyses were carried out on five shallow engineering drilling wells during offshore exploration work at SOCAR. These studies aimed to provide a detailed understanding of Quaternary sea-bottom sediments, focusing on their composition, microfauna, stratigraphy, thickness, and physical properties. Such analyses were essential for improving the efficiency and safety of geological exploration and for addressing engineering and geotechnical challenges related to offshore field development (Akhmedov et al., 1998).

A comprehensive exploration incorporating petrophysical interpretations, core and cutting analyses, and seismic data review was undertaken to evaluate the hydrocarbon potential of the Karabakh prospective structure.

Between 1997 and 1998, I served as a biostratigraphy consultant for CIPCO Operation Company, contributing to a study based on cuttings and core samples obtained from three deep exploration wells in the Karabakh region (Table 1).

In 2007, during my tenure at the German company Wintershall, I led the Ashrafi-Karabakh project. As part of the project, the company officially acquired well log data from SOCAR. These data were initially available only in paper format but were later digitized and edited by Petrologic Data Services GmbH. The final dataset was delivered in LAS digital format with a sampling interval of 0.1524 meters. I extend special thanks to my former colleague, Mr. Richard Culpman, whose rigorous quality control confirmed the reliability of the log data for the Karabakh-2 and Karabakh-3 wells. For other intervals, only low-resolution composite logs were available. Consequently, the detailed analysis and fulfilment of the project objectives were achievable primarily for the Karabakh-2 and -3 wells, while interpretations for the Karabakh-1 well should be regarded as qualitative rather than quantitative.

In collaboration with Mr. Culpman, we conducted petrophysical interpretations of the Karabakh wells. All formation tops in the logs were corrected by me. A standard deterministic interpretation was carried out using Interactive Petrophysics software under the supervision of Mr. Culpman.

Prior to 1997, during my service as an offshore exploration geologist at SOCAR, I performed biostratigraphic analyses on five shallow engineering drilling wells. These studies aimed to achieve a detailed understanding of Quaternary sea-bottom sediments, focusing on their composition, microfauna, stratigraphy, thickness, and physical properties. Such insights are critical not only for enhancing the efficiency and safety of geological exploration but

also for addressing engineering and geotechnical challenges associated with offshore field development (Akhmedov et al., 1998).

A comprehensive exploration encompassing petrophysical interpretations, core and cutting analyses and a review of seismic data facilitated an assessment of the hydrocarbon potential of the Karabakh prospective structure**.**

Geological and Geophysical Exploration

Initial exploratory activities commenced in 1993 with two wells drilled by the State Oil Company of the Azerbaijan Republic (SOCAR). Well No. 1 targeted the Pliocene Gala Formation at a projected depth of 4200 meters but was abandoned at 720 meters due to technical difficulties. Well No. 2, also targeting the Gala Formation, was terminated at 1567 meters upon reaching the Surakhany suite for similar reasons (Javadova, 2005).

Subsequent exploration between 1996 and 1998 involved 3D seismic surveys by international operators and the drilling of three additional wells (KPS-1, KPS-2, and KPS-3) by a foreign consortium. These wells intersected sedimentary sequences ranging from the Quaternary to the Miocene (Fig. 2).

- **KPS-1** (central axis): drilled to 3840 m; targeted Productive Series.
- **KPS-2** (southwestern flank): reached 3809 m.
- **KPS-3** (northern flank): drilled to 3766 m.

The primary objective was to evaluate the hydrocarbon potential of the Balakhany (Horizons X, IX, and VIII) and Fasila Formations. Due to limited reservoir quality and hydrocarbon shows in these zones, deeper secondary targets in the Lower and Upper Kirmaki formations were also evaluated.

Table 1

List of the studied core and cutting materials

Structure/ field name	**well №**	**Penetrated well depth**	**number of core sample and sludge cuttings**	**Core intervals (m)**
Karabakh	8	0-150	10	0-5; 10-20;35-38; 38-43; 40-55; 60-65; 75-80; 80-85; 90-100; 145-150
	3	0-200	8	0-5; 5-10; 20-30; 55-60; 190-200; 970-975; 976-980; 1055-1065
	24	0-150	5	0-10; 20-30; 30-40; 90-100; 140-150
	4	0-100	4	0-10; 40-50; 70-80; 90-100
	2	755-900	6	655-665; 680-690 ; 690-1000 ;1050-1060; 1060-1070;1100-1110
	KPS-3	330-3723	core - 2; cuttings - 617	cuttings: 330-1000 m every 10 m;.1003-3425 m every 5 m; 3425-3445 m every 3 m; 3445-3766 m every 5 m; Core: 3701-3712.20 m; 3712.20-3723 m
	KPS-2	3407-3419	5	3407-3408 m; 3408-3409 m; 3409-3416 m; 3416-3418 m; 3418-3419 m
	KPS-1	1000-3840	cuttings - 95; core - 29	cuttings 328-1000 m every 10 m; 1000-3485 m every 3 m; core: 3610-3619 m; 3753-3762 m; 3762-3840 m every 3 m

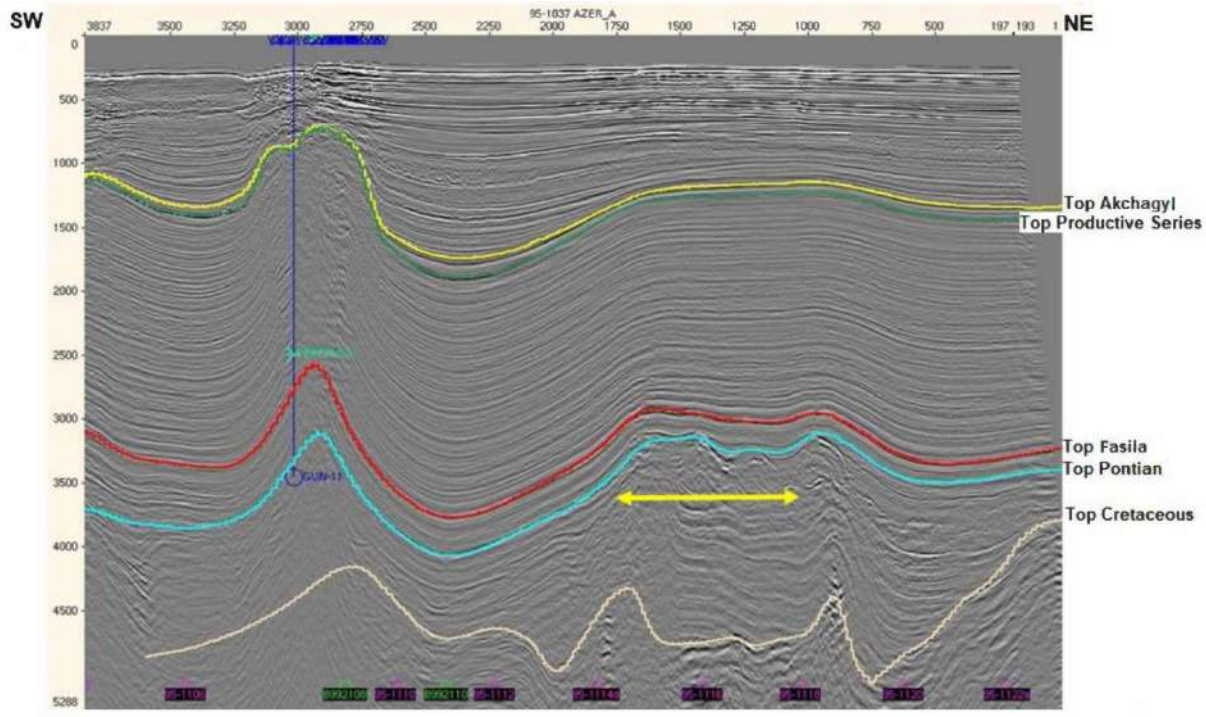

Fig. 2. Seismic section over Karabakh field

Tectonic Setting

- Tectonically, the Karabakh field lies within the North Absheron uplift zone, a region characterized by intense Neogene folding and faulting. All local structures of the zone where the located Karabakh field are characterized by small sizes (5-10x12 km), inconsiderable amplitudes (100-200 m), flanks of least dip (up to 7-12º) and their echelon joint. The arches of the structures are usually broad and without faults. Their structure gets more complex with depth (Babayev, Gadjiev, 2006). Structural geometries of the Karabakh field include asymmetrical and locally overturned anticlines segmented by longitudinal (thrust and strike-slip) and transverse faults. The Karabakh fold trends NW–SE and comprises two domal culminations (Javadova, 2019).

The structure is further complicated by latitudinal and longitudinal fault systems, particularly in its axial part, where the amplitude of displacement ranges from 50 to 120 meters. The southwestern flank exhibits dips of 18-20°, whereas the northeastern flank dips at 9-10°, increasing with depth. These structural features suggest a syndepositional tectonic regime and pose challenges for uniform geological prediction across the field. (La Bella et al., 1996) (Fig. 3).

Stratigraphy and Lithological Characteristics

The stratigraphic column of the Karabakh area can be subdivided into four main intervals (Fig. 4):

1. **0-700 m (Quaternary):** Unconsolidated sandy-argillaceous sediments with drilling difficulties due to low compaction.
2. **700-2220 m (Absheron–Akchagyl and Upper Productive Series):** Transitional sequence with increasing lithological stability.
3. **2220-3500 m (Productive Series):** Comprising the lower Surakhany, Sabunchu, Balakhany, Fasila, and Upper Kirmaki formations.

>3500 m: Lower Kirmaki sediments and deeper sequences.

The lithology predominantly consists of hard, grey sandstone-siltstone interbeds with compact plastic clays. Reservoir properties of key formations are summarized below:

Formation	Sand Content (%)	Average Porosity (%)
Balakhany	60	19.0
Fasila	65	20.2
Upper Kirmaki (Sandy)	75	22.0

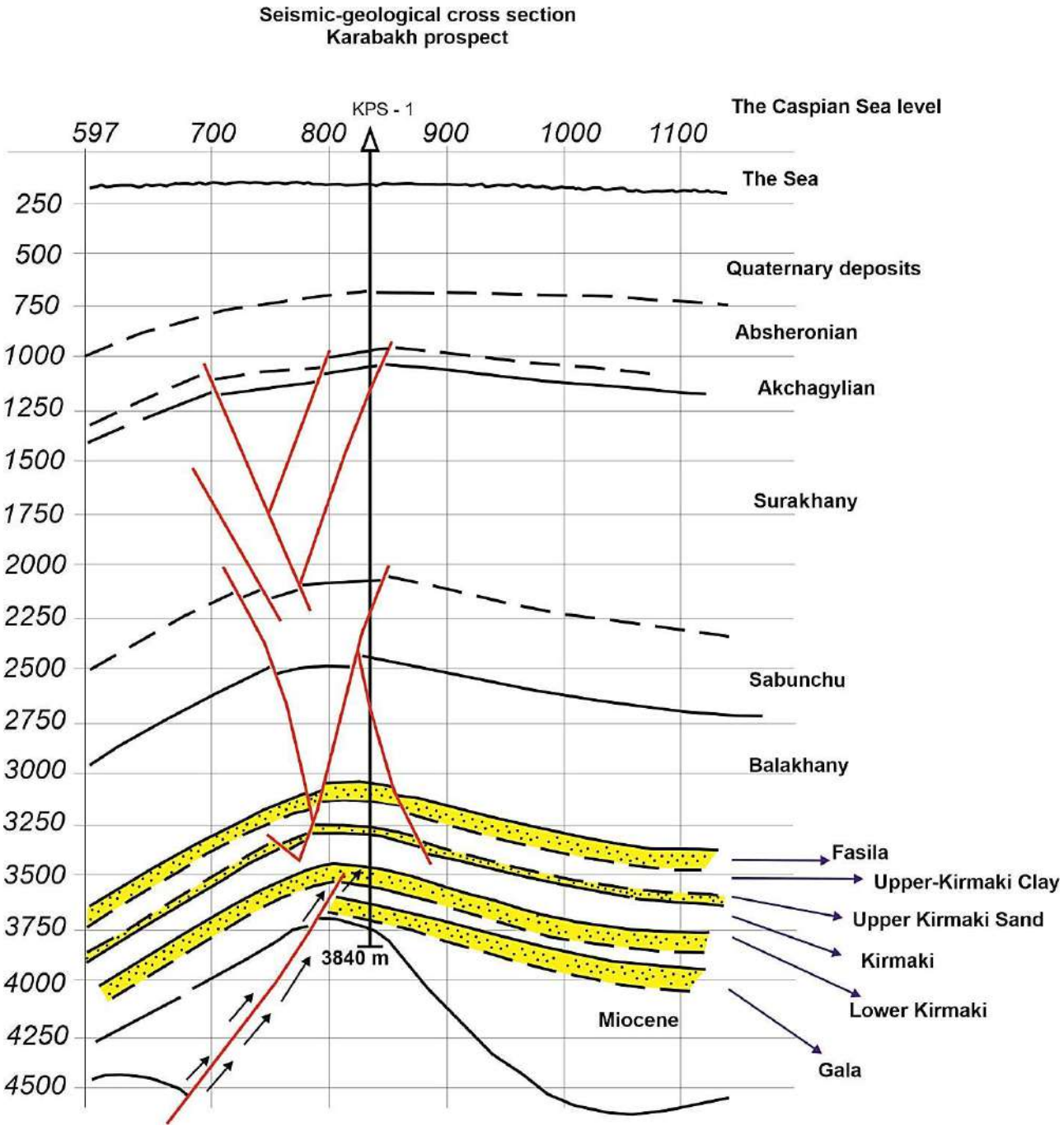

Fig. 3. Seismic-geological cross section Karabakh prospect

From a lithological perspective, several important characteristics of the layers merit attention. Clay-rich intervals, particularly below the Surakhany suite, exhibit swelling behavior that complicates drilling operations and wellbore stability.

It should be noted that the Upper Kirmaki sandy formations in the Absheron archipelago areas are characterized by lithological stability, it can be assumed from well KPS-1 data that the Upper Kirmaki sandy formation did not undergo any considerable lithofacial changes in the Karabakh prospect.

Clay-rich intervals, particularly below the Surakhany suite, exhibit swelling behavior that complicates drilling operations and wellbore stability (Table 2).

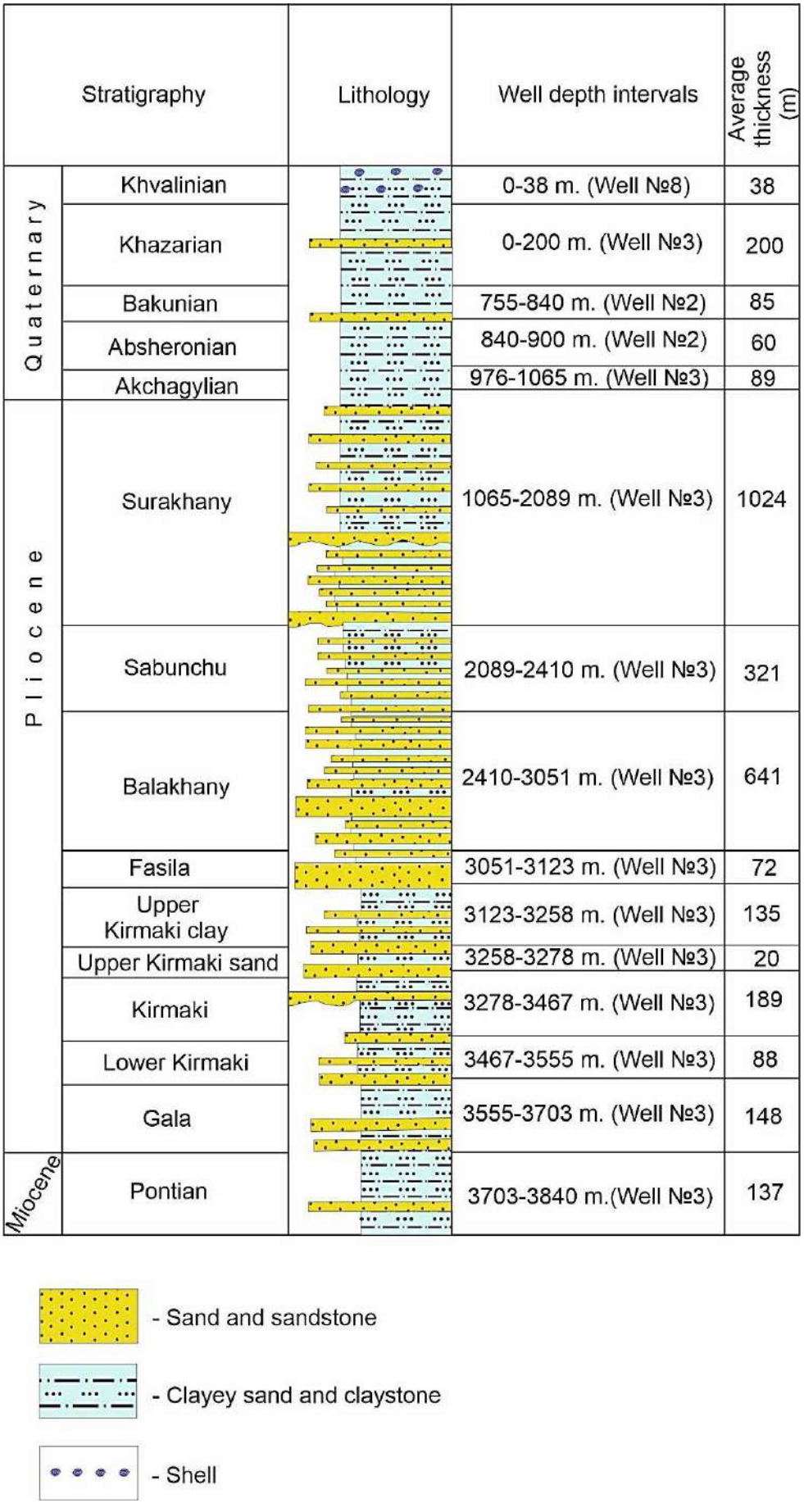

Fig. 4. Stratigraphy chart of the Karabakh field

Table 2

Formation top and lithology of Karabakh wells

Stratigraphy		KPS-1			KPS-2			KPS-3		
		depth, in m	thickness in m	lithology description	depth, in m	thickness in m	lithology description	depth, in m	thickness in m	lithology description
Quaternary	Pleistocene+ Holocene	202-328	126	No samples	198-330	132	No samples have been collected	203-330	127	No samples have been collected
		328-705	377	Claystone grey, plastic, soft, sticky, locally silty to sandy with fossil fragments	330-728	398	Clay/claystone, light grey to grey, plastic, soft, sticky, water sensitive, locally silty, to sandy with fossils fragments	330-728	398	Clay/claystone, light grey to grey, plastic, soft, sticky, water sensitive, locally silty, to sandy with fossils fragments
	Absheron	705-976	271	Claystone grey, plastic, soft, sticky, locally silty to sand	728-1046	321	Clay/claystone, grey, plastic, soft, sticky, water sensitive, locally silty to sandy	728-1061	333	Clay/claystone, grey, plastic, soft, sticky, water sensitive, locally silty to sandy
Upper Pliocene Akchagyl		976-1065	89	Claystone dusky yellow, variable grey, locally silty with trace of Pyrite	1046-1145	84	Clay/claystone; grey to dark grey, light brown in parts , soft, to firm with streaks, of siltstone; light brown, to beige, soft to firm, pyritic in parts	1061-1145	84	Clay/claystone; grey to dark grey, light brow, in parts, pyritic in parts
Middle Pliocene Productive strata (upper part)	Surakhany	1065-2089	1024	Claystone dusky yellow, olive grey, plastic, soft, sticky with common anhydrite stringers and intercalated. Sandstone quartzose is very fine to fine-grained, subrounded to subangular, loose, friable, moderately well sorted, calcareous cement, argillaceous matrix	1145-2257	1112	Claystone: grey, to dark grey, brown, orange, soft to firm, blocky with common, gypsum/anhydrite stringers, and intercalated Sandstone: quartzose, very fine, to fine grained, subrounded, to subangular, loose, friable, poor to moderately, sorted, calcareous/dolomitic, cement. Traces of pyrite are associated with the sandstone throughout the section	1145-2257	1112	Claystone: grey, to dark grey, gypsum/anhydrite stringers with intercalated Sandstone: quartzose, very fine, to fine grained, subrounded, to subangular, loose, friable, poor to moderately, sorted, calcareous/dolomitic, cement.

	Sabunchu	2089-2449	360	Claystone brownish, grey, blocky to platy, partly soft, soft, plastic, sticky with interbeds of sandstone: quartzous, very fine grained, subrounded to subangular, fairly sorted, calcareous cement, argillaceous matrix	2257-2511	254	Claystone brown, to dark brown, reddish in part, moderately hard, silty. Siltstone light brown, to beige, reddish in part, firm grading to very fine, sandstone. With streaks of sandstone: quartzose, light brown, to beige, off white in part, friable, very fine grained, subangular to subrounded, it moderately sorted, calcareous cement, argillaceous matrix	2257-2558	301	Claystone/Silstone from olive grey, to brown, and dark brown, with interlayers of Sandstone quartoze, light brown, to beige, off white in part, friable, very fine grained, subangular to subrounded, light brown, to beige, off white in part, friable, very fine grained, subangular to subrounded,
	Bala-khany-V	2449-2547	98	Claystone olive grey, dusky yellow, yellowish brown, firm, blocky, with sandstone, interbeds, which become progressively thinner and more frequent with depth. Sandstone: quartzous, very fine to fine-grained, partly medium, subrounded to subangular, grained, poorly sorted, calcareous cement, argillaceous matrix. Traces of pyrite are associated with the sandstone throughout the section	2511-2596	85	Claystone/Siltstone olive Grey, dusky yellow, yellowish brown, firm blocky with sandstone interbeds which become progressively thinner and more frequent with depth. Sandstone quartoze, white, cream, colorless, fine to medium grained, subangular to subrounded, moderately sorted, calcareous/dolomitic cement. Traces of pyrite are associated to the sandstone throughout the section	2558-2649	91	Claystone oil grey , with thin interlayers of sandstone quartoze, medium grained, subangular to subrounded, moderately sorted, calcareous cement, argillaceous matrix
	Balakhany-VI	2547-2624	77		2596-2658.5	62.5		2649-2701	52	
	Balakhany-VII	2624-2707	83		2658.5-2737	78.5		2701-2791	90	
	Bala-khany-VIII	2707-2830	123		2737-2952	215	claystone with sandstone streaks	2791-2981	190	Sandstone with interlayers of claystone
	Bala-khany-IX	2830-2957	127		2952-3102.5	150.5	claystone with thin sandstone layers	2981-3120	139	
	Balakahny-X	2957-3051	94		3102.5-3177	74.5		3120-3214	94	Two horison of sandstone with interlayers of claystone, Sandstone quartoze, white, cream, colorless, fine to medium grained, subangular to subrounded, moderately sorted, calcareous/dolomitic cement
	Fasila	3051-3150	99	Two sandstone bodies with an intermediate and basal claystone development. Sandstone: quartzous, very fine to medium-grained, locally coarse, garined, subrounded to subangular, unconsolidated, traces	3177-3287	110	Sandstone with shale beds	3214-3311	97	

				of pyrite. Claystone olive brown, yellowish brown, firm, blocky, to subfisssile, locally silty to sandy.						
Middle Pliocene Productive strata (Lower part)	Upper Kirmaki clayey	3150-3258	108	Claystone grey to dark grey, firm, subblocky, becoming very fissile, to splintery, calcareous, locally silty	3287-3403	116	Claystone grey, to dark grey, firm, subblocky, becoming very fissile, to splitery, slightly, calcareous, locally, silty, Traces of micromicaceous materials.	3311-3426.5	115.5	Claystone, locally silty
	Upper Kirmaki sandy	3258-3467	209	Claystone dark grey, to grey, firm, fissile, to splintery, concave, calcareous, silty in part, becoming very silty, downward, grading to siltstone, locally sandy, with interbeds of sandstone: quartzous, very fine to coarse, grained, unconsolidated, subrounded to subangular, to subrounded, poorly sorted, argillaceous, matrix, calcareous cement	3403-3432.5	29.5	Sandstone with thin shale layers	3426.5-3469	42.5	Sandstone with interlayers of claystone. Claystone grey, to dark grey, firm, subblocky
	Kirmaki suite	3284-3467	183		3432.5-3618	185.5	Claystone pale to light, grey, soft, firm, subblocky, platy, rare, subfissile, silty in parts, grading to siltstone, calcareous	3469-3652	183	Claystone dark grey, to grey, calcareous,
	Lower Kirmaki-1 sand	3467-3518	19		3618-3643	25	Sandstone quartzose, colourless, smokey, grey, very fine grained, subangular to subrounded, well sorted, calcareous, cement, argillaceous, matrix, poor, visible porosity. Interbedded with claystone: pale grey, soft subblocky, silty, in parts, slightly to very calcareous.	3652-3672	20	Well-sorted sandstone, subangular, to subrounded, with interlayers of claystone, calcareous, traces of pyrite, plastic, argillaceous, matrix, calcareous cement
	Lower Kirmaki-2 sand	3486-3518	32		3643-3673	30	Sandstone with claystone layers	3723-3750	27	
	Lower Kirmaki-3 sand	3518-3553.5	35.5		3673-3691	18		3672-3723	51	
	Gala suite	3553.5-3597	43.5	Claystone dark, to light grey, soft, firm, blocky, platy , rare sub fissile, silty in parts, grading to	3691-3737	46	Claystone pale grey, soft to firm subblocky, silty in parts, slightly to very calcarous. Traces of pyrite, with streaks of sandstone: quartzose,	3723-3750	27	

				siltstone, calcareous			**colourless, very fine-grained, subangular, to subrounded, well sorted, calcareouse cement, argillaceous matrix, poor visible porosity.**			
	Gala suite sandy	**3597-3703**	**106**	**Claystone dark grey, to grey, firm, fissile, to splintery, concave, calcareous, silty in part, with thin interbedded of sandstone: quartzose, very fine-grained, subangular, to subrounded, well sorted traces of pyrite**	**3737-3769**	**32**				
	Pre Gala suite	**3703-3840**	**137**	**Claystone is dark to light grey, light green, soft, firm, blocky, sub-fissile, very calcareous, and silty in part grading to siltstone. With thin beds of sandstone: quartzous, very fine to fine grained, raree medium grained, subangular, to subrounded, poorly sorted, traces of pyrite.**	**3769-3795**	**26**	**Claystone pale grey to dark grey, occasionally pale, grey brown, soft to firm, subblocky, to platy, silty in parts, slightly to very calcareous. Traces of carbonaceous materials and pyrites**			
					unconformity					
Mio-cene	**Meotian**				**3795-3809**	**14**				

During drilling of the Gala suite and Miocene Formations in the KPS-1 well, the extrusion and leakage of a plastic, lutea-like material from the open borehole zone were observed. This material appears to have formed due to the saturation of siltstones and compacted clays with high-pressure water and hydrocarbons that migrated into the overlying clay layers from underlying deposits. Swollen clay facies are particularly common in fluid-conducting fracture zones within the clay cap rock. These clays tend to concentrate along the migration paths of high-pressure fluids and are primarily extruded into the wellbore. Additionally, they swell further under the influence of drilling mud filtrate, increasing in plasticity and susceptibility to creep.

To assess the wellbore stability of the KPS-1 in the 3750-3840 m interval, pre-stressed clay rocks in this section were studied. Potential time windows for the onset of drilling issues were also identified. Comparative analysis indicates that such problems are not typical at shallower depths, such as in the Lower Kirmaki suite (3500-3550 m) or the Gala suite (3600-3700 m).

The borehole narrowing, clay extrusion, and formation of clay lumps observed during drilling of the Gala suite and Miocene Formations are attributed to the widespread presence of montmorillonite clays. Notably, in the adjacent Guneshli area, montmorillonite content reaches up to 30% in the Upper Kirmaki sandy, Kirmaki, and Lower Kirmaki suites, and up to 40% in the Gala suite. It is likely that similar montmorillonite concentrations exist in these suites within the Karabakh area as well. A sharp increase in montmorillonite content (up to 20-30%) in loose clay sludge is considered indicative of the proximity to a large, high-pressure hydrocarbon accumulation.

Comparative analysis of subsurface conditions in Karabakh and adjacent fields

Regional data analysis reveals that the stratigraphic layers in the lower part of the Productive strata are characterized by unstable pore pressure, even within individual layers. For instance, in the Fasila suite at the adjacent Chirag field, pore pressure in well No. 6 ranges from 35.5 to 44.6 MPa. Similarly, in the Upper Kirmaki sandy, pore pressure in well No. 4 varies from 38.6 to 51.3 MPa, with corresponding changes in pore pressure gradients in the clay formations.

These variations in fluid pressure between adjacent intervals of differing lithology are attributed to the differing influence of overlying rocks on impermeable clay layers versus permeable reservoirs with a rigid framework. Such localized instability in pore pressure across narrow depth intervals often results in wellbore erosion.

Abnormally high reservoir pressures are consistently observed in the same stratigraphic layers of the lower Productive Series – specifically in the Upper Kirmaki sandy, Kirmaki suite, and the basement complex – across all nearby wells, including Chirag No. 4 and No. 6, Novkhany No. 1, Arzu No. 2, and Karabakh KPS-1.

Actual data obtained during well targeting in the Novkhany prospect (formerly Nakhchivan), well No. 1; Guneshli No. 5; Chirag No. 4 and No. 6; Hazri No. 4; Gilavar No. 2; and Karabakh KPS-1 provides a basis for predicting potential drilling challenges in any future planned new wells at the Karabakh prospect. These challenges primarily relate to reservoir overpressure and hydraulic fracture pressures.

Experience from exploration well targeting in these prospects demonstrates that, if appropriate technologies and procedures are followed, drilling can generally proceed without significant issues up to the Kirmaki Formation. However, due to the geological and structural differences in location, the drilling conditions of any newly designed wells in the Karabakh prospect may vary from those encountered in KPS-1.

In the 325-700 m interval, the presence of unconsolidated formations may result in lost circulation. Additionally, shallow epigenetic overpressure zones may be encountered, leading to potential water and gas shows during drilling.

The 700-2100 m interval correlates stratigraphically with the Lower Quaternary deposits of the Absheron and Akchagyl stages of the Surakhany Formation. Within this zone, minor gas and water shows may occur due to aquifer penetration or the presence of localized hydrocarbon accumulations.

Mud filtrate invasion into permeable units can lead to wellbore constriction (tight hole conditions). The interval between 2100-3300 m

corresponds to the Sabunchu, Balakhany, Fasila, Upper Kirmaki Clayey, and Upper Kirmaki Sandy formations. Within these formations, drilling may encounter water and gas shows, sloughing, and further tight hole issues due to mud invasion.

Petrophysical Analysis and Hydrocarbon Potential

Well log analysis and formation testing indicate that the Lower Kirmaki formation is predominantly water-bearing (Fig. 4). However, the Upper Kirmaki sandy unit exhibited positive gas log responses, though no direct formation tests were performed at this interval. Tables 3 and 4, along with Figs 5, 6, 7, 8, 9, 10 and 11 show the petrophysical interpretation results of Karabakh wells. The clay volume was determined using the GR log. The porosity was calculated from the sonic log. Where available (in Karabakh 3 only), the neutron porosity has been used. The lithology model contains shale and sandstone. Primary interest is that an oil-water contact can be seen at 3450 m MD in the Upper Kirmaki sandy in Karabakh 3.

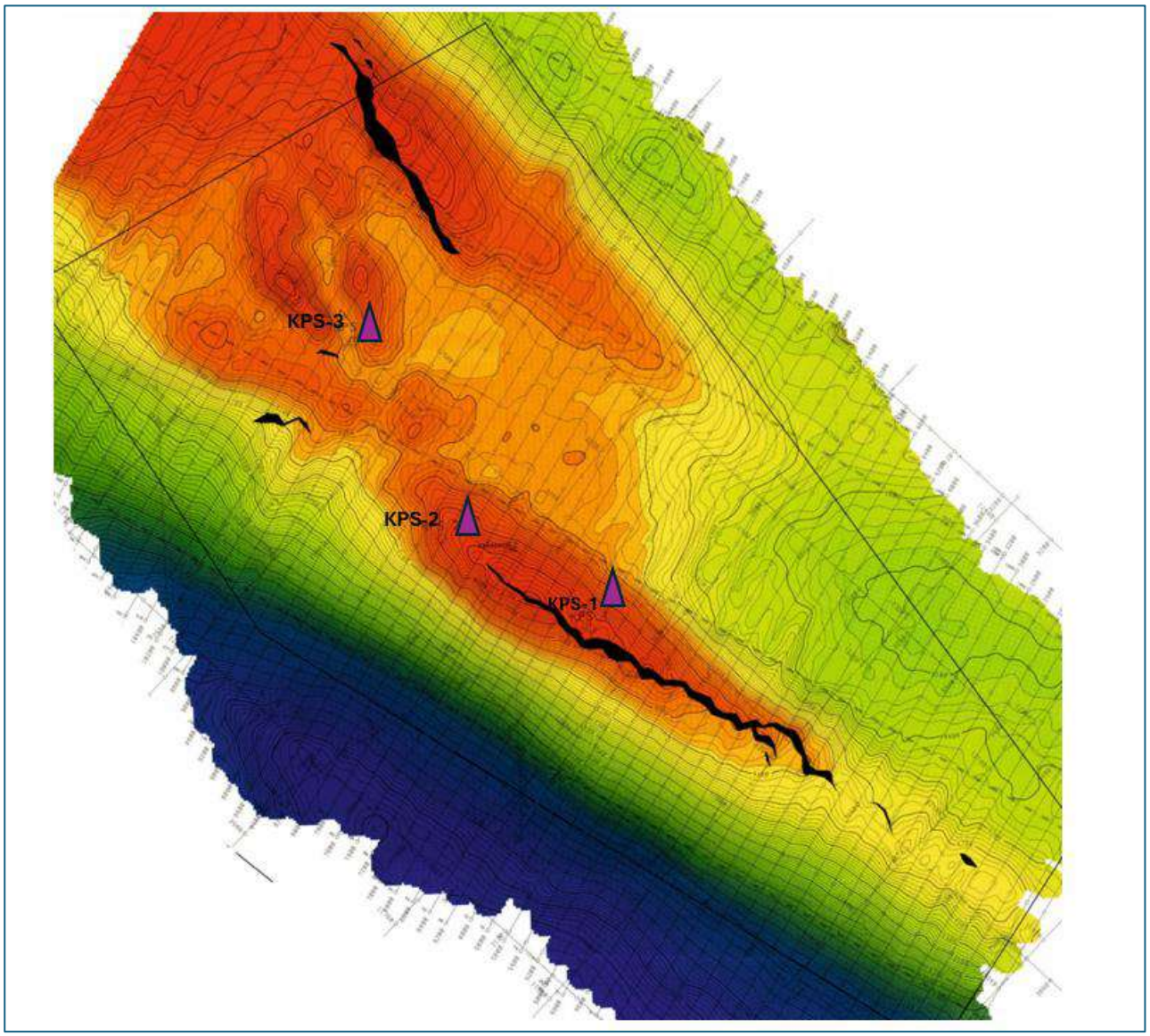

Fig. 5. Base Productive depth map with location of the drilled wells in Karabakh field (modified after Azerbaijan Petroleum Industry Review, 2007)

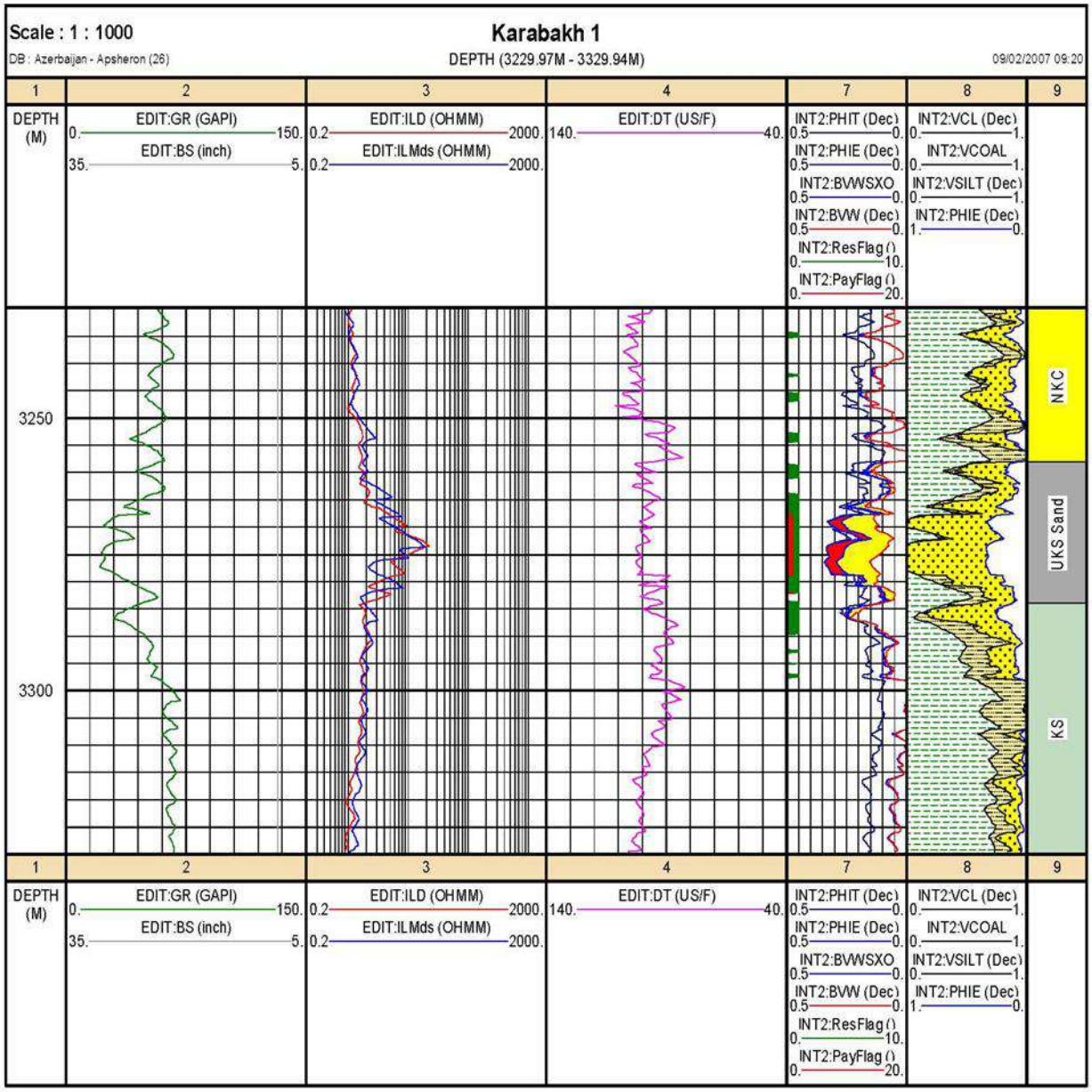

Fig. 6. Karabakh KPS-1 well log at Upper Kirmaki sandy (UKS) level

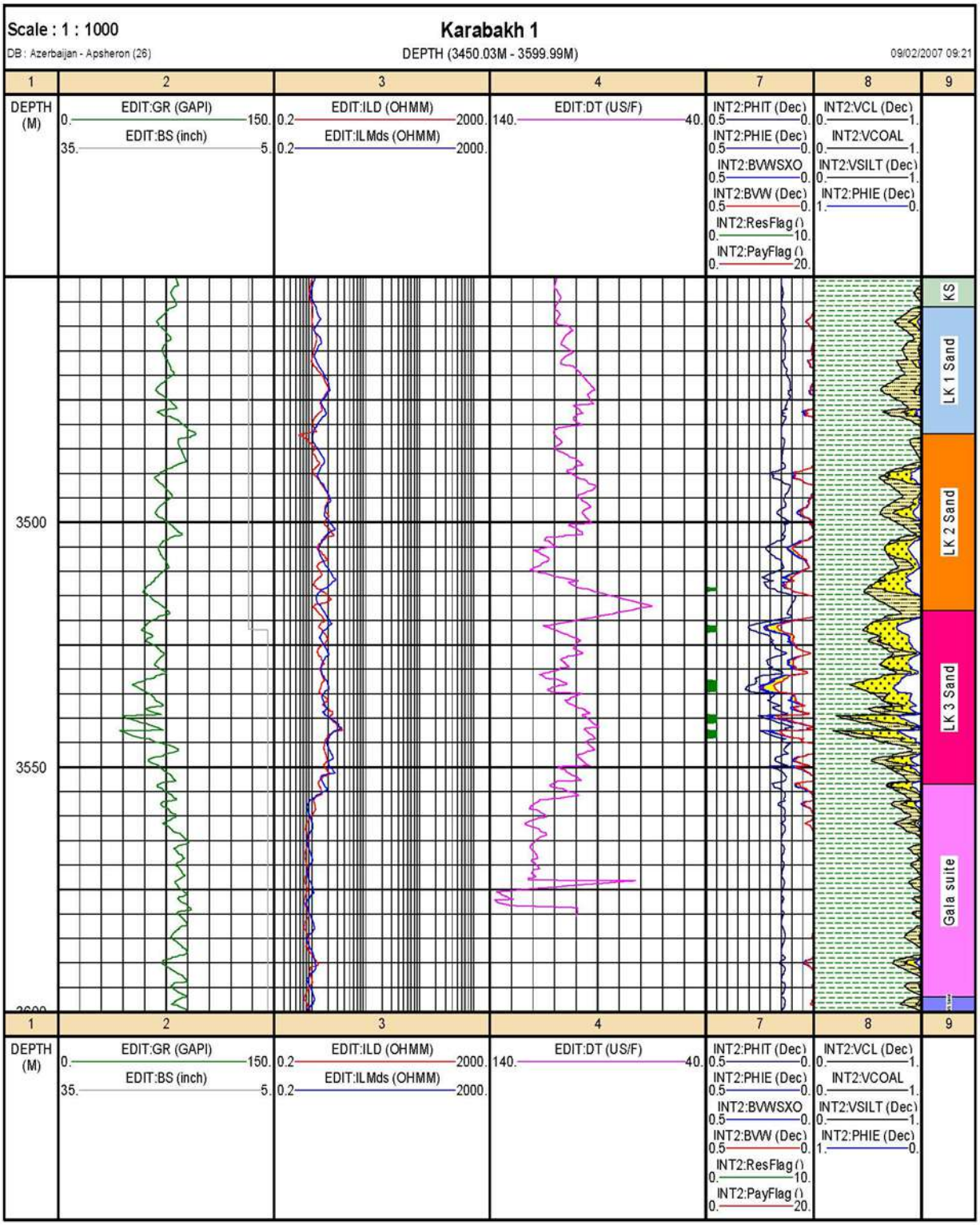

Fig. 7. Karabakh KPS-1 well log.at Lower Kirmaki (LK) level

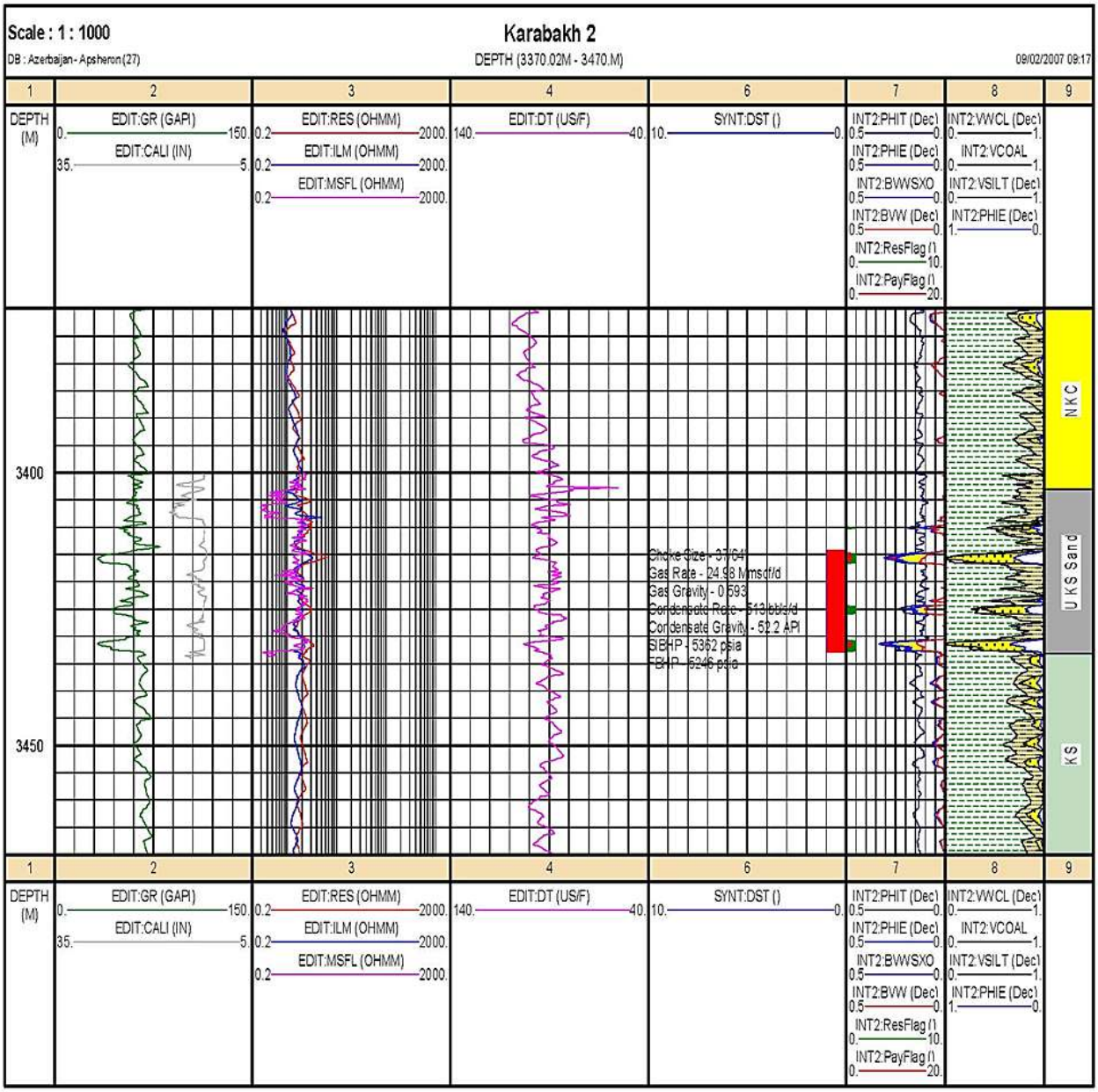

Fig. 8. Karabakh KPS-2 well log at Upper Kirmaki sandy (UKS) level

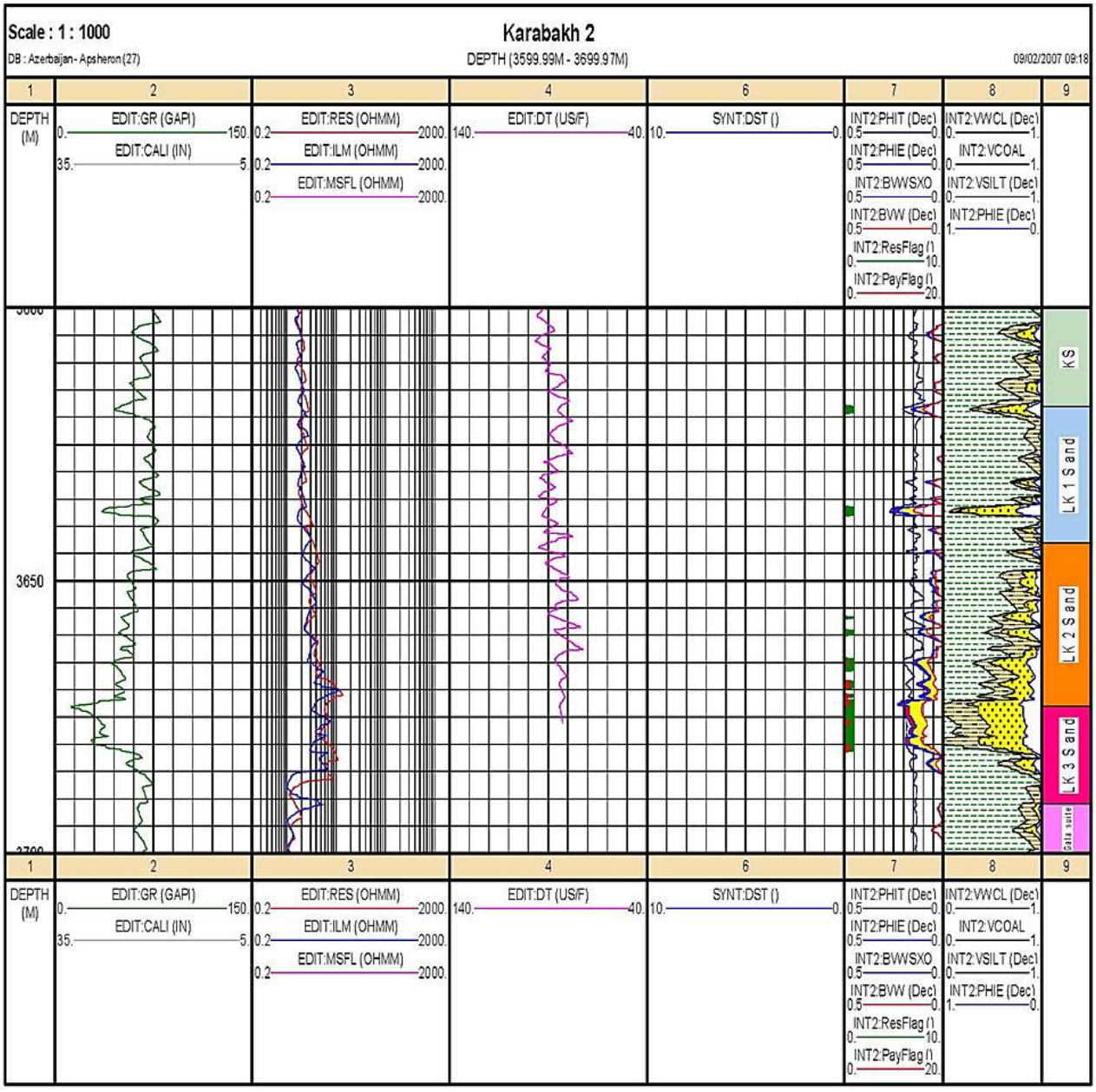

Fig. 9. Karabakh KPS-2 well log at Lower Kirmaki (LK) level

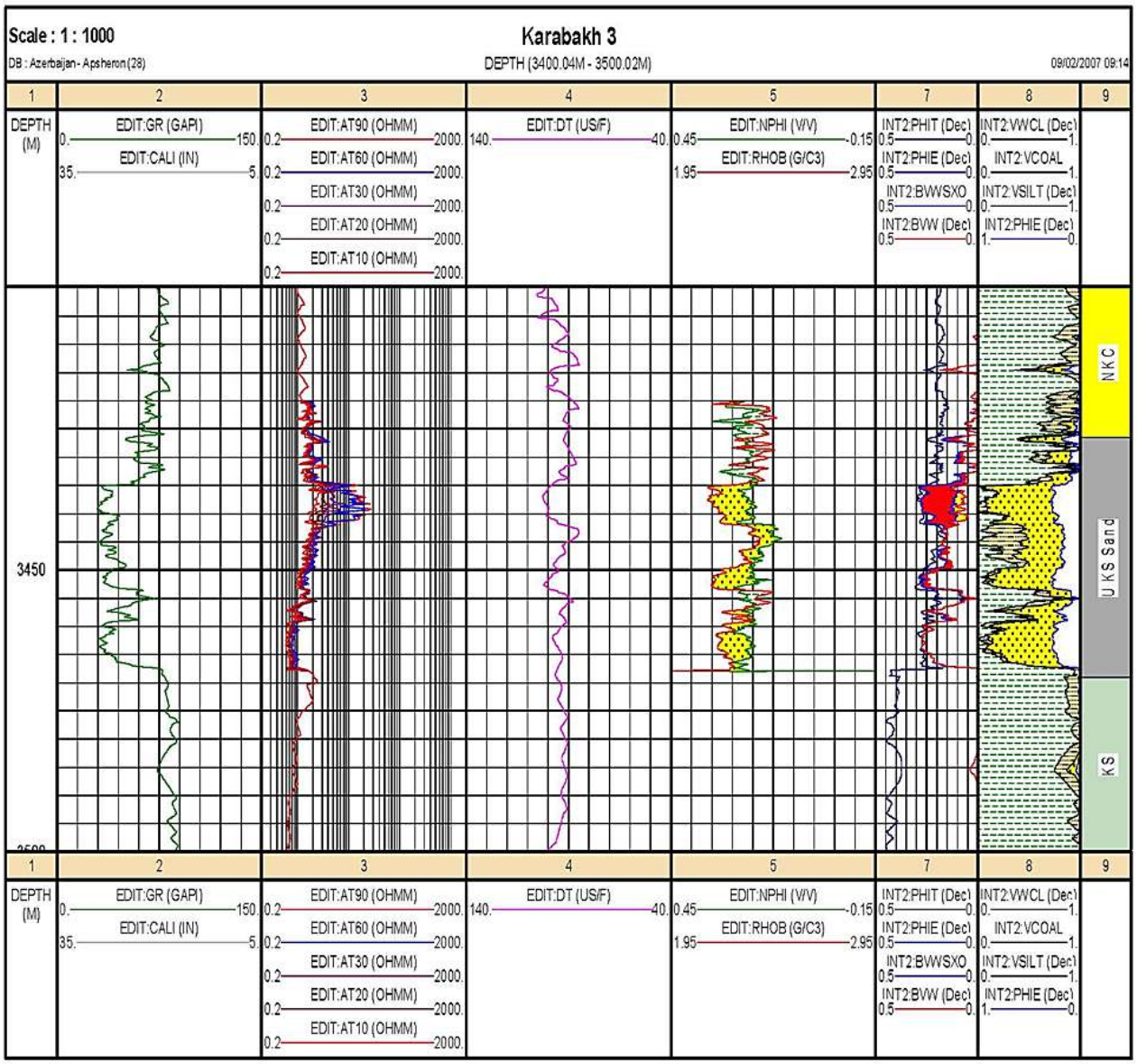

Fig. 10. Karabakh KPS-3 well log at the Upper Kirmaki sandy (UKS) level

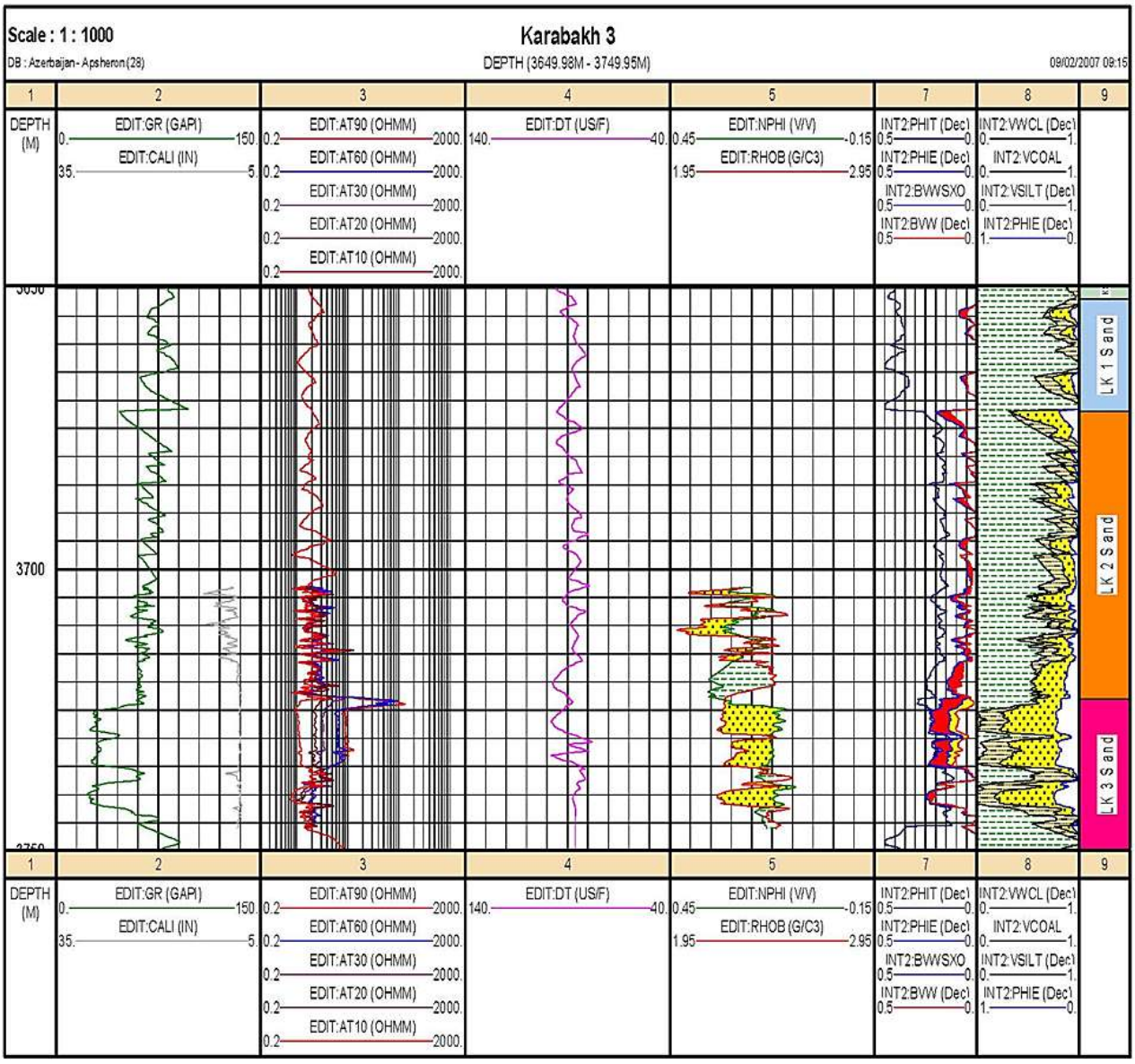

Fig. 11. Karabakh KPS-3 well log at the Lower Kirmaki (LK) level

Table 3

Reservoir summary of Karabakh wells

Reservoir summary

Well	Zone Name	Type	Units	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl	Phi*H	PhiSo*H
Karabakh 1	Fasila	MD	m	3048.61	3150.00	101.39	62.03	0.61	0.23	1.00	0.17	14.35	0.04
Karabakh 1	UKC	MD	m	3150.00	3258.00	108.00	4.57	0.04	0.17	0.94	0.42	0.75	0.05
Karabakh 1	UKS Sand	MD	m	3258.00	3284.00	26.00	21.04	0.81	0.23	0.53	0.19	4.78	2.26
Karabakh 1	**KS**	**MD**	**m**	**3284.00**	**3455.98**	**171.98**	**6.85**	**0.04**	**0.17**	**0.97**	**0.26**	**1.16**	**0.04**
Karabakh 1	LK 1 Sand	MD	m	3455.98	3481.88	25.90	0.00	0.00	---	---	---	---	---
Karabakh 1	LK 2 Sand	MD	m	3481.88	3518.00	36.12	0.61	0.02	0.11	---	0.49	0.07	---
Karabakh 1	LK 3 Sand	MD	m	3518.00	3553.50	35.50	6.71	0.19	0.19	0.82	0.38	1.28	0.23
Karabakh 1	**All Zones**	**MD**	**m**	**3048.61**	**3553.50**	**504.89**	**101.80**	**0.20**	**0.22**	**0.88**	**0.21**	**22.40**	**2.60**
Karabakh 2	Fasila	MD	m	3177.00	3287.00	110.00	65.84	0.60	0.22	0.97	0.13	14.56	0.40
Karabakh 2	UKC	MD	m	3287.00	3403.00	116.00	0.00	0.00	---	---	---	---	---
Karabakh 2	UKS Sand	MD	m	3403.00	3432.50	29.50	5.10	0.17	0.22	0.50	0.18	1.11	0.55
Karabakh 2	**KS**	**MD**	**m**	**3432.50**	**3618.00**	**185.50**	**0.94**	**0.01**	**0.14**	**0.74**	**0.45**	**0.13**	**0.03**
Karabakh 2	LK 1 Sand	MD	m	3618.00	3643.00	25.00	3.10	0.12	0.19	0.60	0.23	0.60	0.24
Karabakh 2	LK 2 Sand	MD	m	3643.00	3673.00	30.00	3.74	0.13	0.13	0.51	0.36	0.50	0.24
Karabakh 2	LK 3 Sand	MD	m	3673.00	3691.00	18.00	8.91	0.50	0.14	0.32	0.28	1.23	0.84
Karabakh 2	**All Zones**	**MD**	**m**	**3177.00**	**3691.00**	**514.00**	**87.63**	**0.17**	**0.21**	**0.87**	**0.16**	**18.13**	**2.31**
Karabakh 3	Fasila	MD	m	3214.00	3311.00	97.00	70.60	0.73	0.25	1.00	0.13	17.31	0.03
Karabakh 3	UKC	MD	m	3311.00	3426.50	115.50	0.32	0.00	0.16	0.84	0.40	0.05	0.01
Karabakh 3	UKS Sand	MD	m	3426.50	3469.00	42.50	30.31	0.71	0.22	0.75	0.16	6.67	1.69
Karabakh 3	**KS**	**MD**	**m**	**3469.00**	**3652.00**	**183.00**	**0.00**	**0.00**	---	---	---	---	---
Karabakh 3	LK 1 Sand	MD	m	3652.00	3672.00	20.00	0.15	0.01	0.20	0.63	0.31	0.03	0.01
Karabakh 3	LK 2 Sand	MD	m	3672.00	3723.00	51.00	3.35	0.07	0.14	0.61	0.41	0.48	0.19
Karabakh 3	LK 3 Sand	MD	m	3723.00	3750.00	27.00	15.09	0.56	0.20	0.53	0.07	3.04	1.43
Karabakh 3	**All Zones**	**MD**	**m**	**3214.00**	**3750.00**	**536.00**	**119.83**	**0.22**	**0.23**	**0.88**	**0.14**	**27.58**	**3.36**

Table 4

Pay summary of Karabakh wells

Well	Zone Name	Type	Units	Top	Bottom	Gross	Net	N/G	Av Phi	Av Sw	Av Vcl	Phi*H	PhiSo*H
Karabakh 1	Fasila	MD	m	3048.61	3150.00	101.39	62.03	0.61	0.23	1.00	0.17	14.35	0.04
Karabakh 1	UKC	MD	m	3150.00	3258.00	108.00	4.57	0.04	0.17	0.94	0.42	0.75	0.05
Karabakh 1	UKS Sand	MD	m	3258.00	3284.00	26.00	21.04	0.81	0.23	0.53	0.19	4.78	2.26
Karabakh 1	**KS**	**MD**	**m**	**3284.00**	**3455.98**	**171.98**	**6.85**	**0.04**	**0.17**	**0.97**	**0.26**	**1.16**	**0.04**
Karabakh 1	LK-1 Sand	MD	m	3455.98	3481.88	25.90	0.00	0.00	---	---	---	---	---
Karabakh 1	LK-2 Sand	MD	m	3481.88	3518.00	36.12	0.61	0.02	0.11	---	0.49	0.07	---
Karabakh 1	LK-3 Sand	MD	m	3518.00	3553.50	35.50	6.71	0.19	0.19	0.82	0.38	1.28	0.23
Karabakh 1	**All Zones**	**MD**	**m**	**3048.61**	**3553.50**	**504.89**	**101.80**	**0.20**	**0.22**	**0.88**	**0.21**	**22.40**	**2.60**
Karabakh 2	Fasila	MD	m	3177.00	3287.00	110.00	65.84	0.60	0.22	0.97	0.13	14.56	0.40
Karabakh 2	UKC	MD	m	3287.00	3403.00	116.00	0.00	0.00	---	---	---	---	---
Karabakh 2	UKS Sand	MD	m	3403.00	3432.50	29.50	5.10	0.17	0.22	0.50	0.18	1.11	0.55
Karabakh 2	**KS**	**MD**	**m**	**3432.50**	**3618.00**	**185.50**	**0.94**	**0.01**	**0.14**	**0.74**	**0.45**	**0.13**	**0.03**
Karabakh 2	LK-1 Sand	MD	m	3618.00	3643.00	25.00	3.10	0.12	0.19	0.60	0.23	0.60	0.24
Karabakh 2	LK-2 Sand	MD	m	3643.00	3673.00	30.00	3.74	0.13	0.13	0.51	0.36	0.50	0.24
Karabakh 2	LK-3 Sand	MD	m	3673.00	3691.00	18.00	8.91	0.50	0.14	0.32	0.28	1.23	0.84
Karabakh 2	**All Zones**	**MD**	**m**	**3177.00**	**3691.00**	**514.00**	**87.63**	**0.17**	**0.21**	**0.87**	**0.16**	**18.13**	**2.31**
Karabakh 3	Fasila	MD	m	3214.00	3311.00	97.00	70.60	0.73	0.25	1.00	0.13	17.31	0.03
Karabakh 3	UKC	MD	m	3311.00	3426.50	115.50	0.32	0.00	0.16	0.84	0.40	0.05	0.01
Karabakh 3	UKS Sand	MD	m	3426.50	3469.00	42.50	30.31	0.71	0.22	0.75	0.16	6.67	1.69
Karabakh 3	**KS**	**MD**	**m**	**3469.00**	**3652.00**	**183.00**	**0.00**	**0.00**	**---**	**---**	**---**	**---**	**---**
Karabakh 3	LK-1 Sand	MD	m	3652.00	3672.00	20.00	0.15	0.01	0.20	0.63	0.31	0.03	0.01
Karabakh 3	LK-2 Sand	MD	m	3672.00	3723.00	51.00	3.35	0.07	0.14	0.61	0.41	0.48	0.19
Karabakh 3	LK-3 Sand	MD	m	3723.00	3750.00	27.00	15.09	0.56	0.20	0.53	0.07	3.04	1.43
Karabakh 3	**All Zones**	**MD**	**m**	**3214.00**	**3750.00**	**536.00**	**119.83**	**0.22**	**0.23**	**0.88**	**0.14**	**27.58**	**3.36**

All wells drilled in the Karabakh field – KPS-1, KPS-2, and KPS-3 – were ultimately abandoned due to geological reasons. However, well KPS-2 yielded successful testing results. Two productive intervals were identified:

- From 3665.5 to 3681 m (Lower Kirmaki/LK Suite), the well produced **30 t/d of condensate** and **773,000 m³/d of gas**.
- From 3414 to 3433 m (Upper Kirmaki sandy/ UKS Suite), it produced **82 t/d of condensate** and **700,000 m³/d of gas**.

In well KPS-1, geophysical data indicated a gas-bearing interval between 3265 and 3278 m (UKS Suite), although no production test was reported.

No testing was conducted in well KPS-3. Two primary hydrocarbon-bearing intervals have been delineated:

- **Lower Kirmaki suite (LK)**: Gas-condensate
- **Upper Kirmaki sandy suite (UKS)**: Oil/condensate with a gas cap

Well targeting analysis in adjacent prospects indicates that drilling conditions in the lower part of the Productive strata differ significantly from those encountered in the Karabakh prospect. Exploration in adjacent Ashrafi and Karabakh fields supports the presence of commercial hydrocarbons within these formations (Babayev, Gadjiev, 2006). Nevertheless, due to the limited number of drilled wells and insufficient well testing, spatial variability and reservoir heterogeneity remain unresolved.

Conclusion

1. **Hydrocarbon Potential Confirmed**: The Karabakh field exhibits confirmed gas-condensate and oil/condensate accumulations within the Lower and Upper Kirmaki formations, based on positive log responses and production testing in KPS-2. The UKS suite is particularly promising, showing significant gas and condensate yields.
2. **Stratigraphic and Structural Complexity**: The area presents considerable geological complexity, with asymmetric folding, fault segmentation, and significant lithological variability. These features pose challenges for reservoir continuity predictions and well placement.
3. **Reservoir Quality**: Reservoirs within the Balakhany, Fasila, and especially the Upper Kirmaki formations demonstrate good sand content (up to 75%) and porosity values (~22%), suggesting favorable conditions for hydrocarbon storage and flow.
4. **Drilling Challenges Identified**: Issues related to clay swelling, borehole instability, overpressured zones, and high montmorillonite content were encountered during drilling, particularly in the Gala and Miocene formations.
5. **Pressure Variability**: Abnormally high and variable pore pressures were observed in multiple formations. This highlights the necessity for careful wellbore pressure management and mud weight control during drilling.
6. **Underexplored Structure**: Only three wells (KPS-1, KPS-2, KPS-3) were drilled, with limited testing conducted. This has left significant uncertainty in reservoir characterization, continuity, and lateral extent.

Recommendations

1. **Further Appraisal Drilling**: Additional wells should be strategically placed along the flanks and crest of the structure to improve spatial resolution, validate reservoir connectivity, and better define hydrocarbon contacts.
2. **Comprehensive Testing**: Conduct complete formation testing in future wells, particularly in promising zones identified in KPS-1 and KPS-3, to assess productivity and fluid properties directly.
3. **Enhanced Well Planning**: Implement advanced wellbore stability models that account for clay swelling and overpressured intervals. Pre-drilling geomechanical modelling should be mandatory to mitigate drilling risks.
4. **Extended Seismic Analysis**: Update and refine 3D seismic interpretation to resolve fault systems, dome culminations, and potential trap geometries more accurately. Pay special attention to lateral sealing faults and stratigraphic pinch-outs.
5. **Petrophysical Re-evaluation**: Reassess existing log data using advanced interpretation techniques (e.g., NMR, dielectric logging) to characterize better characterise fluid types,

saturations, and porosity in heterogeneous reservoirs.

6. **Pressure Management Strategy**: Establish a detailed pore pressure prediction and monitoring framework to safely navigate high-pressure zones and reduce the risk of kicks or losses during drilling.
7. **Comparative Regional Study**: Continue integrating regional data from adjacent fields (e.g., Guneshli, Chirag, Ashrafi) to inform predictive models on stratigraphy, pressure regimes, and reservoir behaviour.
8. **Economic Assessment**: Following successful appraisal, initiate an economic feasibility study including development planning, considering offshore infrastructure constraints, potential tie-backs, and phased production scenarios.

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ПЕРСПЕКТИВЫ ОСВОЕНИЯ КАРАБАХСКОГО МЕСТОРОЖДЕНИЯ В ЮЖНО-КАСПИЙСКОМ БАССЕЙНЕ

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Резюме. Месторождение Карабах, расположенное в северной части Абшеронского архипелага в пределах Южно-Каспийского бассейна, обладает значительным потенциалом углеводородов, главным образом в нижне- и верхнекирмакинских толщах. Изначально месторождение было открыто в 1998 году консорциумом Caspian International Operating Company. В 1999 году проект был приостановлен, когда цена нефти составляла 25-26 долларов за баррель. Несмотря на открытие залежей, проект был закрыт, поскольку запасы нефти и газа были признаны экономически нецелесообразными для разработки. Однако в 2018 году началось его освоение в рамках контракта, подписанного между SOCAR и Equinor.

Геологические исследования, включая стратиграфию, каротаж и петрофизическую интерпретацию, проводились по данным трёх скважин (KPS-1 — KPS-3), при этом наибольший успех испытаний был достигнут на скважине KPS-2. Положительные результаты по газу и конденсату были получены из интервалов: подкирмакинская и надкирмакинская песчаная, что подтверждает коммерческую перспективность месторождения.

Структурная сложность региона — выраженная асимметричными складками, надвигами и литологической изменчивостью — создаёт значительные трудности при разведке и бурении. Стратиграфический анализ выявил мощную толщу песчано-глинистых отложений, при этом ключевые коллекторы характеризуются высокой пористостью (до 22%) и песчанистостью (до 75%). Проведение буровых работ осложнялось нестабильными пластовыми давлениями, набуханием глин и зонами аномально высоких давлений, особенно в калинской и миоценовой свитах. Наличие глин, богатых монтмориллонитом, дополнительно ухудшает устойчивость ствола скважины.

Сравнительный региональный анализ и исторические данные по соседним месторождениям подтверждают потенциал Карабаха, но подчёркивают необходимость дальнейшей оценки. Среди рекомендаций — целевое бурение, улучшенный сейсмический анализ, обновлённая петрофизическая интерпретация и строгий контроль давления. Устранение этих технических и геологических неопределённостей является ключевым условием для раскрытия полного экономического потенциала месторождения Карабах и обеспечения безопасного и эффективного освоения на шельфе.

Ключевые слова: *Южно-Каспийский бассейн, разведка нефти и газа, петрофизический анализ каротажных диаграмм, литология, стратиграфия, бурение*

CƏNUBİ XƏZƏR HÖVZƏSİNDƏ QARABAĞ YATAĞININ ÖYRƏNİLMƏSİ PERSPEKTİVLƏRİ

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Xülasə. Qarabağ yatağı Cənubi Xəzər hövzəsinin Şimal Abşeron arxipelaqında yerləşir və əsasən Aşağı və Yuxarı Kirməki laylarında əhəmiyyətli karbohidrogen potensialına malikdir. Yataq ilk dəfə 1998-ci ildə Caspian International Operating Company konsorsiumu tərəfindən kəşf edilmişdir. 1999-cu ildə neftin bir barelinin qiyməti 25-26 ABŞ dolları olduğu dövrdə layihə dayandırılmışdır. Yataqların aşkar edilməsinə baxmayaraq, ehtiyatların iqtisadi baxımdan səmərəsiz hesab olunması səbəbindən layihə bağlanmışdır. Lakin 2018-ci ildə SOCAR və Equinor arasında imzalanmış müqavilə çərçivəsində yatağın işlənməsi yenidən başlamışdır.

Geoloji tədqiqatlar – stratigrafiya, quyu karotajı və petrofiziki interpretasiya daxil olmaqla – üç quyudan (KPS-1-dən KPS-3-ə qədər) əldə edilən məlumatlar əsasında aparılmış, ən uğurlu hasilat sınağı KPS-2 quyusunda qeydə alınmışdır. Həm Alt Kirməki, həm də Üst Kirməki qumlu intervallarından qaz və kondensat üzrə müsbət nəticələr əldə olunmuşdur ki, bu da yatağın kommersiya baxımından perspektivliyini göstərir.

Rayonun struktur mürəkkəbliyi – assimmetrik qatlardan, itələnmə qırılmalarından və litoloji dəyişkənlikdən ibarət olması – kəşfiyyat və qazma proseslərini əhəmiyyətli dərəcədə çətinləşdirir. Stratigrafik qiymətləndirmələr qum-gil ardıcıllığından ibarət qalın layların mövcudluğunu göstərir; əsas kollektorlar yüksək məsaməlilik (22%-ə qədər) və qumluluq (75%-ə qədər) dəyərlərinə malikdir. Qazma işləri qeyri-sabit lay təzyiqləri, gil şişməsi və xüsusilə Qala və Miosen laylarında yüksək təzyiq zonaları səbəbindən çətinləşmişdir. Montmorillonitlə zəngin gil minerallarının mövcudluğu quyu dayanıqlığını daha da mürəkkəbləşdirir.

Regional müqayisəli təhlil və qonşu yataqlardan əldə edilən tarixi məlumatlar Qarabağ yatağının potensialını təsdiqləyir, lakin əlavə qiymətləndirməyə ehtiyac olduğunu göstərir. Tövsiyələrə məqsədyönlü qazma işlərinin aparılması, təkmilləşdirilmiş seysmik analiz, yenilənmiş petrofiziki interpretasiya və ciddi təzyiq nəzarəti daxildir. Bu texniki və geoloji qeyri-müəyyənliklərin aradan qaldırılması Qarabağ yatağının tam iqtisadi potensialının reallaşdırılması və təhlükəsiz, səmərəli dəniz əməliyyatlarının təmin edilməsi üçün vacibdir.

Açar sözlər: *Cənubi Xəzər hövzəsi, neft və qaz kəşfiyyatı, karotaj diaqramlarının petrofiziki təhlili, litologiya, stratiqrafiya, qazma*

Stratigraphy, petroleum sedimentology, geochemistry **2 / 2025**

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Theory section should extend, not repeat the background to the manuscript already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis.

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Each figure (map, diagram, scheme, etc.) should be presented as a separate object in the end of the text or as file in JPEG (*.jpeg, *.jpg). As a rule, their sizes should not exceed 7.75 cm in the width. It should not exceed the width of text margin (16.5 cm) and located symmetrically relatively the middle of page. Picture caption should be carried out by font – 12pt (bold), the caption (deciphering of conditional signs, explanation etc.) font TNR – 12 pt in italics. Each figure and caption should be on one page, and figure caption is under the figure.

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Hasanov T.Ab. Ophiolites of Lesser Caucasus. Nedra. Moscow, 1985, 240 p. (in Russian).

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Bortnikov N.S. Geochemistry and origin of ore forming fluids in hydrothermal-magmatic systems in tectonically active zones. Geology of ore fields. Vol. 48, No. 1, 2006, pp. 3-28 (in Russian).

Examples of References for the paper submitted in English

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Dearing J. Magnetic susceptibility. In: Walden J., Smith J.P., Oldfield F. (Editors). Environmental Magnetism: a practical guide, Quaternary Research Association. Technical Guide, No. 6, London 1999, pp. 35-62.

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Example of References for the paper submitted in Azerbaijani (or Russian) languages

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Azərbaycan Respublikası əhalisinin siyahıyaalınması. 2009-cu il. XIX cild, Bakı, 2011, 820 s.

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Suleymanov M.A. Geographical laws of natural and anthropogenic landscapes of Azerbaijan. Abilov, Zeynalov ve ogullari. Baku, 2005, 248 p. (in Azerbaijani)

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Reference to a journal publication:

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Reference to book:

Mustafayev G.V. Mesozoic granitoid formations of Azerbaijan and peculiarities of its metallogeny. Elm. Baku, 1977, 234 p. (in Russian).

Reference to a chapter in an edited book:

Mettam G.R., Adams L.B. How to prepare an electronic version of your article. In: Introduction to the Electronic Age. E-Publishing Inc., New York, 2009, pp. 281–304.

Reference to dissertation and/or Abstract of dissertation (known as Avtoreferat):

Garibov Y.E. Anthropogenous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Reference to Conferences and Symposia

Khain V.Ye. Northcaucasian-Turkmeno-Northafganian Late Triassic volcano-plutonic belt and detection of north zone of Tethys. Doklady AS of USSR, Vol. 249, No. 5, 1979, pp. 1190-1192 (in Russian).

Reference to a website:

Cancer Research UK. Cancer statistics reports for the UK. 1975, http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/ accessed 13 March 2003).

Reference to a dataset (methodological recommendation booklet):

Oguro M., Imahiro S., Saito S., Nakashizuka T. Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, Vol. 1, 2015.

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MÜƏLLİFLƏR ÜÇÜN QAYDALAR

"Stratigrafiya, neft sedimentologiyası, geokimya" jurnalının redaksiya heyəti məqalələri, icmal xarakterli məlumatları, müzakirələri və qısa məlumatları qəbul edir. Məqalələr İngilis, Rus və Azərbaycan dillərində təqdim edilə bilər.

Nəşr edildikdən sonra məqalələrə fərdi DOI identifikatoru verilir.

Məqalənin adı

Şrift: Times New Roman (TNR) – 12 pt, bütün hərflər böyük, qalın olmalı, səhifənin ortasında tam eninə (16,5 sm) simmetrik yerləşdirilməlidir. Sonra bir interval buraxaraq müəlliflərin soyadı və adının baş hərfləri yazılmalıdır. Məqalənin adı orijinalda rus və ingilis tərcümələrinə uyğun olaraq yazılmalıdır.

Müəlliflərin inisialı və soyadı, işlədikləri təşkilatın adı

Şriftin ölçüsü – 11 pt, kiçik hərflərlə səhifənin mərkəzinə simmetrik yerləşdirilməlidir. Aşağıda təşkilatın adı, poçt ünvanı iki nöqtə ilə – müəllifin e-mail ünvanı (bütün mərhələlərdə, eləcə də nəşrdən sonrakı yazışmalar və müraciətlər üçün). Şrift – 11 pt, kursiv, kiçik hərflərlə, səhifənin tam eninə simmetrik yerləşdirilməlidir.

Müəlliflər aşağıdakı ardıcıllıqla qeyd edilməlidir: əvvəlcə soyad, sonra isə inisial. Əgər müəlliflər fərqli təşkilatlarda işləyirlərsə, inisialdan sonra yuxarı indeksdə rəqəm qoyulmalıdır. Soyad və inisialdan sonra, növbəti sətirdə müvafiq yuxarı indeks müəlliflərin işlədiyi təşkilatın adı ilə uyğun olaraq yerləşdirilməlidir. Məsələn, aşağıdakı kimi:

Ismail-Zadeh A.J.[1], Musyaev Sh.D.[2], Veliyev Z.A.[1]
[1]*Geology and Geophysics Institute, Azerbaijan National Academy of Sciences*
119, H. Javid Ave., Baku, Azerbaijan, AZ1073: arifismail@mail.ru
[2] *"AzerGold" CJSC*
M.Mushfig Str., 2H, Baku, Azerbaijan, AZ1004

Xülasə

Xülasədə 200-250 söz olmalı və burada tədqiqatın məqsədi, mahiyyəti və lazım gələrsə, metodları (əgər tələb olunursa) izah edilməlidir. "Xülasə" sözü qalın şriftlə çap olunmalıdır. Həm "Xülasə" sözü, həm də mətn 11 pt. şrift ölçüsündə, kiçik hərflərlə yazılmalıdır. Xülasə mətni düsturlardan ibarət olmamalıdır. İstinadlardan istifadə etməyin. Standart olmayan və ya nadir abreviaturalardan çəkinin, lakin lazım gələrsə, onlar ilk dəfə qeyd edildikdə açıq şəkildə göstərilməlidir. Mətnin eni 13,5 sm-dən çox olmamalıdır və səhifəsinin mərkəzində simmetrik yerləşdirilməlidir. Mətndə sətirlər arasındakı məsafə – 1 interval olmalıdır. Xülasə orijinal dildə, rus və ingilis dillərində təqdim olunmalı və həcmi 200-250 söz olmalıdır.

Açar sözlər

Xülasədən sonra 1 interval buraxaraq, maksimum 7 sözdən ibarət açar sözlər yerləşdirilməlidir, bu zaman ümumi və çoxsaylı terminlərdən və anlayışlardan çəkinin (mümkünsə, məsələn, "və" bağlayıcısından istifadə etməyin). "Açar sözlər" iki nöqtə ilə kursiv və qalın şriftlə yazılmalıdır. İki nöqtə işarəsindən sonra açar sözlər kursivlə, vergüllə ayrılaraq yazılmalıdır. Açar sözlər indeksləşdirmə zamanı istifadə olunacaq. Daha sonra 2 intervaldan sonra Giriş yazılmalıdır.

Giriş

İşin məqsədlərini, mövzunun öyrənilməsini göstərin, bu vaxt dərc olunan materialların və ya tədqiqatın nəticələrinin ətraflı icmalından uzaq olun.

Məqalənin tərtibinin tələbləri

Mətnin sərlövhəsinin nömrələnməsi ilə bağlı birbaşa tələblər yoxdur. Müəlliflər sərlövhələri istədikləri stil və formatda çap edə bilərlər. Sərlövhələri nömrələmək və ya nömrələməmək müəlliflərin ixtiyarındadır. Sərlövhələr və yarimsərlövhələr mətndə ayrı bir sətirdə sol tərəfdə ara buraxaraq qalın şriftlə – 14 pt (sərlövhələr üçün) və 12 pt (yarimsərlövhələr üçün) çap olunmalıdır.

Məqalənin mətni

Hər bir abzas səhifənin sol tərəfindən 1 sm aralı başlayır. Mətndə sətirlər arasındakı məsafə – 1,5 interval olmalıdır, məqalə MW formatda çap edilməlidir. Tövsiyə olunan şrift ölçüsü – 14 pt (Times New Roman). Başqa şriftlərdən istifadə etməyin. Məqalələr Azərbaycan, rus və ya ingilis dilində təqdim olunmalıdır. Əgər məqalə azərbaycanca yazılıbsa, xahiş edirik, rus dilində olan versiyasını da əlavə edin. İngiliscə təqdim olunan məqalələrə üstünlük veriləcək.

Məqalənin mətni düzgün formatlanmalı (xüsusilə, bütün sətirlər soldan və sağdan düz olmalı, səhifədən kənara çıxmamalıdır), diqqətlə redaktə olunmalı və coğrafi adların, geoloji terminlərin və beynəlxalq SI sistemindəki simvolların düzgün yazılması baxımından yoxlanılmalıdır.

Səhifənin formatı

Səhifənin formatı A4 ölçüsünə (21,0 x 29,7 sm) uyğun olmalıdır. Kənarlar: soldan – 3 sm, sağdan – 1,5 sm, yuxarıdan və aşağıdan – hər biri 2 sm məsafədə, əlyazmasının səhifələrinin nömrələnməsi – aşağı sağ küncdə olmalıdır.

Material və metodlar

Müstəqil tədqiqatçının işi yenidən çapa edə bilməsi üçün ətraflı məlumat təqdim edin. Bundan əvvəl dərc olunmuş metodları qısa şəkildə izah edin və onlara istinad edin. Əvvəllər dərc olunmuş bir metodu birbaşa sitat gətirəndə onu dırnaq içində yazın və mənbəni göstərin. Mövcud metodların bütün dəyişikliklərini də qeyd etməlisiniz.

Nəzəriyyə və hesablamalar

Nəzəri hissə geniş şəkildə təqdim olunmalı və gələcək işlər üçün əsas yaratmalıdır, girişdə verilmiş məlumatlar təkrarlanmamalıdır. Hesablamalar bölməsi işin praktik hissəsini təsvir edir, bu da işin nəzəri mövqeyini təsdiqləyir.

İllüstrasiyalar, cədvəllər, düsturlar

Hər bir şəkil (xəritə, diaqram, sxem və s.) mətndən sonra ayrı obyekt kimi təqdim olunmalı və ya JPEG (*.jpeg, *.jpg) formatında fayl olaraq göndərilməlidir. Onların ölçüləri, bir qayda olaraq, eni 7,75 sm-i və ya səhifənin kənarlarını (16,5 sm) aşmamalıdır. Şəkillər səhifənin mərkəzində simmetrik yerləşdirilməlidir. Şəklin altındakı yazıların ölçüsü – 12 pt, şəkilaltı yazı mətni (şərti işarələrin izahı və s.) – 12 pt; kursivlə yazılmalıdır. Hər bir şəkil və şəkilaltı mətn eyni səhifədə olmalı, şəkilaltı yazı mətni şəklin altında yerləşməlidir.

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- Vektor təsvirlər CorelDraw, Adobe Photoshop formatında təqdim olunmalıdır.
- Fotolar üçün JPG/JPEG, TIF formatını 300 dpi-dən aşağı olmayan rezolyusiyada istifadə edin.

Cədvəllərin nömrələri və adları onların üzərində 12 pt şriftlə göstərilməlidir. Cədvəllər çox mürəkkəb olmamalıdır və səhifədən kənara çıxmamalıdır. Cədvəlin bir səhifədən digərinə keçməsi qadağandır. Cədvəllər məqalənin mətni içində yerləşdirilməlidir. Cədvəlləri mətndəki yerinə uyğun olaraq bir-birinin ardınca nömrələyin, cədvələ aid qeydləri isə cədvəlin altında yerləşdirin. Cədvəldə qısaltmalara icazə verilmir. Düsturlar araşdırmalar olmadan verilməlidir, istifadə olunan simvolların açılışı (düsturdan dərhal sonra) mütləq olmalıdır və dərəcələrin və alt indekslərin mətndəki düsturun ortasında dəqiq şəkildə yerləşdirilməsi tələb olunur. Düsturların nömrələri, əgər onlara istinad olunursa, düsturun sağ tərəfində, düstur ilə eyni xətdə dairəvi mötərizələr içində göstərilməlidir. Düsturların yazılması üçün Microsoft Equation redaktorundan istifadə edilməlidir. Düstur və düstur nömrəsi olan sətrin eni 7,75 sm-dən çox olmamalıdır.

Nəticələr və/və ya Müzakirələr

Nəticələr aydın və qısa şəkildə təqdim edilməlidir. Müzakirələrdə işin nəticələrinin əhəmiyyəti xüsusi qeyd edilməlidir, nəticələri təkrarlamamalı, çoxsaylı sitatlardan və dərc olunmuş ədəbiyyatın müzakirələrindən çəkinilməlidir. Nəticələr və Müzakirələr bölmələrinin birləşdirilməsi mümkündür.

Nəticələr

Tədqiqatın əsas nəticələri qısa şəkildə təqdim oluna bilər. Nəticələr bölməsi ayrıca yerləşdirilə bilər və ya Müzakirələr və ya Nəticələr və Müzakirələr bölmələrinin alt bölməsi kimi müəlliflərin seçiminə uyğun olaraq, eləcə də məqalənin üslubuna, əldə olunan nəzəri nəticələrə, hesablamalara və s. görə yerləşdirilə bilər.

Ədəbiyyat

Ədəbiyyat aşağıda verilmiş tələblərə və nümunələrə uyğun olmalıdır: nömrələnmədən verilməlidir; orijinal dilindən asılı olmayaraq, ədəbiyyat mütləq ingilis dilində də təqdim olunmalıdır. Əgər ədəbiyyat orijinalda, həm azərbaycanca, həm də rusca təqdim olunubsa, kitabın/məqalənin/ materialın adını ingilis dilinə tərcümə edin, lakin orijinal dili mötərizədə aşağıdakı kimi göstərin: (in Russian).

Nəşriyyatın adını tərcümə etmədən göstərin, məsələn: Nauka, Nedra, Nafta-Press, Elm və s.

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Xahiş edirik, mətndə istinad edilən hər bir ədəbiyyat mənbəyinin ədəbiyyat siyahısında olmasına (və əksinə) diqqət yetirin. Mətndəki istinadlar original dildə verilməlidir.

Bütün istinadlar mətndə mötərizəyə alınmalı və aşağıdakı qaydalara uyğun olmalıdır:

- Bir müəllif: müəllifin soyadı (inisial olmadan), nəşr ili;
- İki müəllif: hər iki müəllifin soyadı, nəşr ili;
- Üç və ya daha çox müəllif: birinci müəllifin soyadı, ardından "et al." (və s.), nəşr ili.

Bir sıra istinadlar xronoloji ardıcıllıqla təqdim olunmalıdır. Məsələn, (Bryulov, 1999; McKenzie, 2000)…". İstinad həmçinin aşağıdakı formada da ola bilər: "Alizadeh et al. (2016) have recently shown …".

Ədəbiyyat siyahısı: İstifadə olunan ədəbiyyat mənbələri əlifba sırasına uyğun olmalıdır. Şriftin ölçüsü – 12 pt. Soyad böyük hərflə başlayır, digər hərflər kiçik olmalıdır, soyaddan sonra vergül olmamalıdır. Soyad(lar)dan sonra jurnalın adı/kitabın adı/ bölmənin adı/məqalənin adı, cild/nömrə, kitabın bölməsi/jurnalın nömrəsi, nəşriyyat, şəhər, nəşr ili və səhifə nömrələri göstərilməlidir. DOI identifikasiya indekslərinin istifadəsi tövsiyə olunur. Eyni müəllifin eyni nəşr ili üçün bir neçə ədəbiyyat mənbəyi varsa, əlavə olaraq "a", "b", "c" və s. hərfləri tətbiq olunmalıdır (Aliyev, 2009a).

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Məqalələrin təqdim edilməsi

Təqdim olunan bütün məqalələr resenziyalaşdırılma və redaksiya heyəti tərəfindən təsdiqlənməyə göndərilir. Bu prosedurdan keçən və müsbət rəy alan məqalələr pulsuz dərc olunur. Müəlliflər əlyazmalarını **"Məqaləni təqdim et" (Submit the manuscript)** funksiyası vasitəsilə onlayn olaraq Redaksiya Heyətinə təqdim etməlidirlər.

Rəy prosesi məqalənin redaksiyaya təqdim olunmasından etibarən **1-2 ay müddətində** davam edir. Məqalələr qəbul edildikləri ardıcıllıqla dərc olunur. Həm kağız, həm də elektron formatda təqdim olunan məqalələrin yüksək peşəkar standartlara uyğun olmasını xahiş edirik. Məqalələrin elektron formatda təqdim edilməsi etibarlılığı, dəqiqliyi və ətraflı məlumatlılığını təmin edərək işinizi yüksək səviyyədə hazırlamağa kömək edəcək.

Məqalə müəlliflərə dəyişikliklər edilməsi üçün qaytarıldıqda, düzəldilmiş variant **iki həftə ərzində** redaksiyaya qaytarılmalıdır. Əgər əlyazma müəllifin günahı üzündən **iki həftədən artıq** gecikərsə, redaksiya tərəfindən məqalə yenidən qəbul olunmuş kimi qiymətləndiriləcək.

Məqaləni təqdim edərkən baş redaktorun adına göndərilən müşayiət məktubunun skan edilmiş elektron versiyasını da göndərməli, məqalənin jurnalın qaydalarına uyğun olaraq baxılması və bütün tələblərə uyğun olduğu halda çap olunması xahiş olunmalıdır.

ПРАВИЛА ДЛЯ АВТОРОВ

Редакционный совет журнала "Stratigraphy, petroleum sedimentology, geochemistry" принимает статьи, обзорную информацию, дискуссии и краткие сообщения. Статьи могут быть представлены на английском, русском и азербайджанском языках.

После публикации, статьям присваивается индивидуальный идентификатор DOI

Название статьи

Шрифт: Times New Roman (TNR) – 12 pt, все буквы заглавные, жирные, следует располагать симметрично относительно середины страницы по всей ширине текстового поля (16,5 см), далее через один интервал печатать фамилии авторов и инициалы. Название печатается на языке оригинала, соответствующего русскому и английскому переводам.

Инициалы и фамилии авторов, название организации, в которой они работают

Размер шрифта – 11 pt, строчные буквы нужно располагать симметрично относительно середины страницы, текстового поля. Далее ниже печатать название организации, ее почтовый адрес и после двоеточия – e-mail автора (для контактов и переписки на всех этапах процесса рецензирования, публикации, а также в период после публикации). Шрифт – 11 pt, курсив, буквы строчные, располагать симметрично относительно середины страницы по всей ширине текстового поля.

Авторов следует указывать в следующем порядке: сначала печатается фамилия, затем инициалы. Если авторы работают в разных организациях, после инициалов следует ставить цифру в надстрочном индексе. После фамилии и инициалов авторов на следующей строке нужно расположить соответствующий надстрочный индекс в соответствии с названием организации авторов. Например, так, как указано ниже:

Ismail-Zadeh A.J.[1], Musyaev Sh.D.[2], Veliyev Z.A.[1]
[1]Geology and Geophysics Institute, Azerbaijan National Academy of Sciences
119, H. Javid Ave., Baku, Azerbaijan, AZ1073: arifismail@mail.ru
[2]"AzerGold" CJSC
M.Mushfig Str., 2H, Baku, Azerbaijan, AZ1004

Резюме

Следует включить резюме из 200-250 слов, описывающих задачи, суть, а также методы (если необходимо) исследования. Слово «Резюме» печатать жирным шрифтом. Как слово «Резюме», так и текст должны иметь размер шрифта – 11 pt., буквы – строчные. Текст резюме не должен содержать формул. Не используйте ссылки. Избегайте нестандартных или редких аббревиатур, но если они необходимы, то должны быть расшифрованы в самом резюме при первом упоминании. Ширина текста не должна превышать 13,5 см, а текст следует располагать симметрично относительно середины страницы. Расстояние между строками в тексте – 1 интервал. Резюме представляются на языках оригинала, русском и английском и должны содержать 200-250 слов.

Ключевые слова

Сразу после резюме через 1 интервал следует расположить ключевые слова, включающие максимум 7 слов, при этом избегайте общих и множественных терминов и понятий (если

возможно, не используйте, например, союз «и»). «Ключевые слова» с двоеточием нужно набирать курсивом и жирным шрифтом. После двоеточия сами ключевые слова печатаются курсивом через запятую. Ключевые слова будут использоваться при индексировании. Далее через 2 интервала печатать Введение.

Введение

Укажите цели работы, изученность темы, при этом избегайте подробного обзора публикаций или результатов исследований.

Требования к оформлению статьи

Нет прямых требований к нумерации заголовков рукописи. Авторы могут печатать заголовок в любом стиле и формате. Можно нумеровать и не нумеровать заголовки (на рассмотрение авторов). Заголовки и подзаголовки следует вставлять в текст в левом поле на отдельной строке с отступом и печатать жирным шрифтом – 14 pt (для заголовков) и 12 pt (для подзаголовков).

Текст статьи

Каждый абзац начинается отступом 1 см от левой границы текстового поля. Расстояние между строками в тексте – 1,5 интервала, текст статьи следует печатать в MW. Рекомендуемый размер шрифта – 14 pt (Times New Roman). Другие шрифты просим не использовать. Статьи представляются на азербайджанском, русском или английском языках. Однако, если они на азербайджанском, пожалуйста, приложите русскую версию рукописи. Предпочтение будет отдаваться статьям, представленным на английском языке.

Текст статьи должен быть отформатирован (в частности, все строки должны быть выровнены слева и справа, не выходя за поле текста), тщательно отредактирован и выверен с точки зрения правильности написания географических названий, геологических терминов и обозначений (в международной системе СИ).

Формат страницы

Формат страницы соответствует формату A4 (21,0 x 29,7 см). Поля: слева –3 см, справа – 1,5 см, снизу и сверху – по 2 см. Нумерация страниц рукописи – в нижнем правом углу.

Материал и методы

Предоставьте детальную информацию, позволяющую воспроизвести работу независимым исследователем. Следует кратко изложить ранее опубликованные методы и указать на них ссылки. При непосредственном цитировании ранее опубликованного метода используйте кавычки и укажите источник. Нужно описывать любые модификации существующих методов.

Теория и расчеты (вычисления)

Теоретическая часть должна излагаться в расширенном виде и создавать основу для дальнейшей работы, а не повторять информацию, приведенную во введении. Раздел Расчеты (вычисления) описывает практическую часть работы, подтверждающую теоретические положения работы.

Иллюстрации, таблицы, формулы

Каждый рисунок (карта, диаграмма, схема и т.д.) представляется в виде отдельного объекта в конце текста или в виде файла в формате JPEG (*.jpeg, *.jpg). Их размеры, как правило, не должны превышать ширины в 7,75 см или текстового поля (16,5 см). Рисунки следует размещать симметрично относительно середины страницы. Размер шрифта подрисуночных подписей – 12 pt, а подрисуночного текста (расшифровка условных обозначений и т.д.) – 12 pt; набирается курсивом. Каждый рисунок и подрисуночный текст должны располагаться на одной странице, причем подрисуночный текст – под рисунком.

Для графической работы рекомендуется использовать следующие правила:

- Для растровых изображений используйте формат JPG/JPEG, TIF при разрешении 300 dpi, 256 градаций серого.
- Векторные изображения следует предоставлять в CorelDraw, Adobe Photoshop.
- Для фотографий применяйте формат JPG/JPEG, TIF при разрешении не менее 300 dpi.

Номера и названия таблиц приводятся шрифтом 12 pt над ними. Таблицы не должны быть громоздкими и выходить за пределы текстового поля. Перенос таблицы с одной страницы на другую не допускается. Таблицы должны быть помещены в текст статьи. Пронумеруйте таблицы одну за другой в соответствии с их местоположением в тексте, а примечания к ним разместите под таблицей. В таблице не допускаются сокращения. Формулы даются без промежуточных выкладок с обязательной расшифровкой используемых в них символов (сразу после формулы) с четким смещением степеней и подстрочных индексов относительно середины строки, содержащей эту формулу. Номера формул, если они упоминаются, указываются в круглых скобках у правой границы текста, на одной линии с формулой. Для набора формул следует использовать редактор Microsoft Equation. Ширина строки с формулой и номером формулы не должна превышать 7,75 см.

Результаты и/или Обсуждения

Результаты должны быть изложены четко и кратко. В Обсуждении следует акцентироваться на значимости результатов работы, а не повторять их, избегая многочисленных цитирований и обсуждений опубликованной литературы. Допускается объединение разделов Результаты и Обсуждение.

Выводы

Основные выводы исследования могут быть изложены кратко. Раздел **Выводы** может располагаться отдельно или образовывать подраздел **Обсуждения** или **Результатов и Обсуждений** по рассмотрению авторов, а также в зависимости от стиля статьи, полученных теоретических результатов, вычислений и т.д.

Литература

Литература должна соответствовать нижеприведенным требованиям и примерам: приводиться без нумерации; независимо от языка оригинала, литература обязательно должна быть дана также на английском языке. Если литература в оригинале дана как на азербайджанском, так и на русском языках, переведите название книги/статьи/материала на английский, но укажите язык оригинала в скобках следующим образом: (in Russian).

Название издательства укажите без перевода, как например: Nauka, Nedra, Nafta-Press, Elm и т.д.

Например:

Garibov Y.E. Anthropogenous transformation of modern landscapes of the Azerbaijan Republic and their optimization ways. Abstract of PhD dissertation (geography), Baku, Azerbaijan, 2013, 47 p. (in Azerbaijani).

Hasanov T.Ab. Ophiolites of Lesser Caucasus. Nedra. Moscow, 1985, 240 p. (in Russian).

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Пример Списка литературы для статьи, представленной на английском языке

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Пример Списка литературы для статьи, представленной на азербайджанском (или на русском) языке

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Пожалуйста, удостоверьтесь, что каждый литературный источник, на который ссылались в тексте, имеется в списке литературы (и наоборот). Ссылки в тексте должны даваться на языке оригинала.

Все ссылки в тексте должны быть заключены в скобки и относиться к:

1. Одному автору: фамилия автора (без инициалов), год издания;
2. Двум авторам: фамилии обоих авторов, год издания;
3. Трем и более авторам: фамилия первого автора, далее следует «et al.» (и др.), год издания.

Ряд ссылок следует представить в хронологическом порядке. Например, (Bryulov, 1999; McKenzie, 2000)…". Ссылка также может быть в следующей форме: "Alizadeh et al. (2016) have recently shown …".

***Список литературы*:** Цитируемые литературные источники должны быть выстроены по алфавиту. Размер шрифта – 12 pt. Фамилия начинается заглавной буквой, остальные буквы строчные без запятой после фамилии. После фамилии(й) автора(ов) указываются название журнала/название книги/название раздела/название статьи, номер тома/ выпуска, глава книги/номер журнала, издательство, город, год издания и номера страниц. Настоятельно рекомендуется использовать идентификационные индексы DOI. В случае нескольких ссылок на литературные источники одного и того же автора и одинакового года издания, следует применить дополнительно буквы "a", "b", "c" и т.д. (Aliyev, 2009a).

Примеры:

Ссылки на журнальные статьи:

Ismayil-zadeh A.J. Bipolar conjugation of volcano-plutonic and ophiolitic belts in Caucasus. Proceedings of NAS of Azerbaijan.The Sciences of Earth, No.1, 2009, pp. 40-53 (in Russian).

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Mettam G.R., Adams L.B. How to prepare an electronic version of your article. In: Introduction to the Electronic Age. E-Publishing Inc., New York, 2009, pp. 281-304.

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Cancer Research UK. Cancer statistics reports for the UK. 1975, http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/ accessed 13 March 2003).

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Oguro M., Imahiro S., Saito S., Nakashizuka T. Mortality data for Japanese oak wilt disease and surrounding forest compositions. Mendeley Data, Vol. 1, 2015.

Представление статей

Все представленные статьи посылаются на рецензирование и одобрение редакционной коллегии. Статьи, которые прошли эту процедуру и получили положительный отзыв, публикуются бесплатно. Авторам следует представлять рукописи в Редакционную Коллегию онлайн посредством функции "**Подать статью (Submit the manuscript)**".

Рецензирование длится **1-2 месяца** со дня представления статьи в редакцию. Статьи публикуются в порядке поступления (очередности). Будем благодарны, если статьи как в бумажном, так и электронном виде будут соответствовать высоким профессиональным стандартам. Представление статей в электронном виде поможет нам подготовить вашу работу наилучшим образом, обеспечивая достоверность, четкость и подробную информативность.

В случае возврата статьи авторам для внесения изменений доработанный вариант должен быть возвращен в редакцию **в течение двух недель**. Если рукопись будет задержана по вине автора **более двух недель**, она будет рассматриваться редакцией как вновь поступившая.

При представлении статьи необходимо прислать также отсканированную электронную версию сопроводительного письма на имя главного редактора с просьбой принять статью на рассмотрение согласно правилам журнала и в случае соответствия всем требованиям опубликовать ее.

Stratigraphy, petroleum sedimentology, geochemistry **2 / 2025**

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ОГЛАВЛЕНИЕ

Jurnal “ZƏRDABİ-NƏŞR” MMC-nin mətbəəsində çap olunmuşdur.

Ünvan: Bakı şəhəri, Nəsimi rayonu, Dilarə Əliyeva küç., 239/8